Analysis of Transportation Responses to Centre Street Bridge Closure

Prepared by:

HBA Specto Incorporated
10 Varmoor Place NW
Calgary, Alberta T3A 0A1
Tel: 403-286-7206
E-Mail: atb@hbaspecto.com

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Land Use and Mobility Department
City of Calgary

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1. Introduction

In August of 1999 the Centre Street Bridge over the Bow River in central Calgary was closed to car and truck traffic for major repairs. The Bridge serves as a major roadway connection between downtown Calgary and residential areas to the north. It normally carries around 34,000 vehicles per day. This closure lasted for a period of 14 months, with the bridge reopening in September of 2000.

In November / December 1999 (i.e. during the bridge closure) the International Results Group (IRG) was contracted by the City of Calgary to survey car users of the Centre Street Bridge and other adjacent roadway bridges in the northern sector of the Downtown. The primary purpose of the survey was to obtain demographic and travel behaviour of car users before and during the bridge closure, to help the City of Calgary Transportation Department (now the Land Use and Mobility Department) understand the impact of a major bridge closure. Just over 1,350 car users of the bridges were surveyed. IRG submitted a report "A Survey and Study on the Centre Street Bridge Closure", which summarized the survey method and results.

In May 2000 HBA Specto consultants were commissioned by the City of Calgary Transportation Department to undertake further analysis of the Centre Street Bridge Closure survey data. This work would complement and add to the Study conducted by IRG.

In particular, the following aspects were to be examined by HBA Specto:

- A comparison of the findings relating to the impact of the Centre Street Bridge Closure with those from other studies of bridge closures.
- Further analysis of the survey data, at an aggregate level.
- Analysis of the survey at a disaggregate individual level for the 1,352 survey respondents.

The purpose of the HBA Specto Study was to provide information to help improve the planning of similar construction-related roadway closures in the future.

This Report describes the results of the HBA Specto analysis. Section 1 is this introduction. Section 2 describes the background to the Centre Street Bridge closure. Section 3 gives details of the survey conducted by IRG, together with a summary of the tabulations produced in their report. Section 4 identifies potential travel behaviour responses to reductions in roadway capacity. Section 5 outlines the findings of other studies on the impact of roadway capacity

reductions. Section 6 gives details of changes in observed traffic and transit flows that occurred on adjacent routes during the Centre Street Bridge closure. Section 7 provides an analysis of the survey data at the aggregate level. Section 8 describes the analysis undertaken at the disaggregate individual level. Section 9 draws conclusions, and assesses implications for future major roadway capacity reduction projects in Calgary.

2. Background to Centre Street Bridge Closure

Centre Street Bridge is one of the major traffic bridges over the Bow River, connecting Downtown Calgary to the north central residential areas. The Bridge has a unique two-tiered deck system.

Fig. 1: Photo of Centre Street Bridge (taken from west)

The upper 4-lane undivided carriageway roadway bridge deck carries Centre Street itself. Centre Street runs north / south through the heart of Calgary. In the Downtown, Centre Street is an integral part of the central arterial roadway circulation system, which is patterned on a grid system with roads every block. In the north central residential areas Centre Street serves as the major arterial roadway. It also connects with 16 Avenue, a major 4-lane east-west arterial route that serves as Highway #1 (the Trans-Canada Highway). In peak hours the Centre Street Bridge and Centre Street North have been operated as a tidal flow lane control system with 3 travel lanes in the peak direction (southbound in the AM; and northbound in the PM); and one travel lane in the reverse direction. In 1999 prior to the closure the Centre Street Bridge upper deck carried around 25,000 vehicles per day on a typical weekday.

The upper deck bridge also serves as a major transit corridor carrying 9 transit routes, and around 13,000 bus passengers on a typical weekday. Sidewalks are also provided on both sides, and carry around 2,000 pedestrians and cyclists per day.

The 2-lane lower deck of the Centre Street Bridge carries 2-way traffic connecting the Downtown with Memorial Drive immediately north of the Bow River, a major east-west 4 to 6 lane arterial roadway. In 1999 the lower deck carried around 9,000 vehicles per day.

Details of the bridge closure; the alternative routes available to traffic using the Centre Street Bridge; and the traffic management and transit measures put in place by the City of Calgary to help diverted trips, are given below.

2.1. Bridge Closure Details

Centre Street Bridge is over 80 years old. In 1999 it was nearing the end of its useful life. A $6.7 million rehabilitation project was required to extend its operating life by another 35 to 40 years. It was necessary to close the bridge to general traffic for an extended 14-month period from August 1999 to September 2000, in order to allow the necessary repairs to be undertaken.

A key challenge in the construction work was the need to maintain one lane operational at all times for the use of transit and emergency vehicles. This was done both to minimize the impact of the project for existing transit users; and also to provide a high quality transit service as an alternative to car users affected by the closure.

In addition, use of the Bridge by pedestrians and cyclists was maintained as much as possible, although there were occasional short periods of time within some days when this was not possible.

2.2. Availability of Alternative Routes

There are four other bridges directly connecting Downtown Calgary and the north central residential areas of the City.

On the west side of downtown the 4-lane Louise Bridge carries two-way traffic connecting 9th Street downtown to the 4-lane arterial Memorial Drive and the 4-lane arterial 10th Street on the north, a major north-south route. It is located around 1.5 km west of the Centre Street Bridge. It currently carries around 32,000 vehicles per day.

Also on the west side of downtown, the 4-lane 14th Street (Mewata) Bridge carries two-way traffic north-south on 14th Street, which runs to the west of downtown. Access ramps from 14th Street connect to Bow Trail, a major 6-lane east-west artery that enters the downtown to become 9th Avenue, and exits the downtown from 4th Avenue. The 14th Street bridge is located about 2.2 km west of the Centre Street Bridge. The connecting ramps from 14th Street to Bow Trail have traffic flows counted separately from those on 14th Street and Bow Trail, and combine to carry around 12,000 vehicles per day.

On the east side of Downtown there are three bridges: the Langevin (Edmonton Trail) Bridge and the two Memorial Drive bridges.

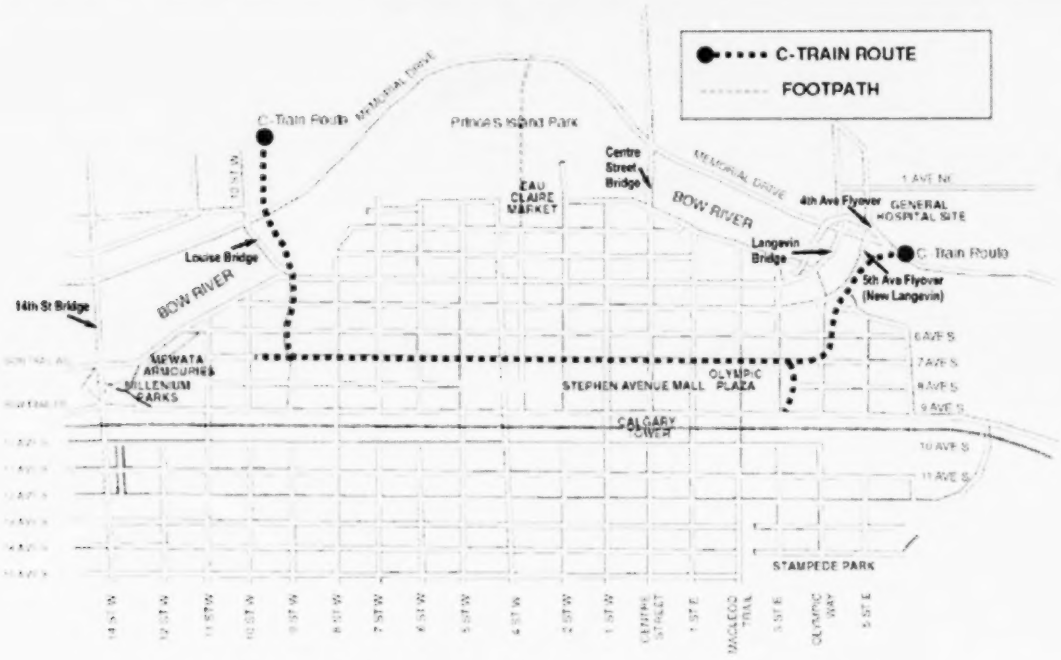
The Langevin Bridge is a 2-lane facility carrying one way traffic connecting both Edmonton Trail, a 4-lane arterial facility running north serving north central Calgary (via one-way 4 St NE) and Memorial Drive to 4 Ave downtown. As mentioned above the lower deck Centre Street Bridge also connects to Memorial Drive, which is a major east-west 4 to 6 lane arterial roadway. The Langevin Bridge is about 0.8 km east of the Centre Street Bridge. It currently carries around 16,000 vehicles per day.

The two Memorial Drive bridges are the 5th Ave Flyover and the 4th Ave Flyover. The 5th Ave Flyover (which is also called the New or Outbound Langevin Bridge) is a one-way structure with four outbound lanes connecting 5th Ave downtown to both northbound Edmonton Trail and east/westbound Memorial Drive. The 4th Ave Flyover is also a one-way structure; it has two inbound lanes and connects westbound Memorial Drive to 4th Ave downtown. The 5th Ave Flyover is about 0.9 km east of the Centre Street Bridge, and the entrance to the 4th Ave Flyover is about 1.0 km east of the Centre Street Bridge. The 5th Ave Flyover carries about 39,000 vehicles per day; the 4th Ave Flyover carries about 30,000.

In addition, there are two east-west entrances to the downtown worth mentioning; Bow Trail, on the west end of the downtown, and 9th Ave SE, to the east of the downtown. Bow Trail is a major 6-lane arterial road running west of the Downtown to a number of residential areas to the east, as well as connecting with Crowchild Trail, a major six-lane arterial road that runs north-south, crossing the Bow River immediately to the north of its' interchange with Bow Trail. About 50,000 vehicles per day use Bow Trail to enter or exit the downtown.

9th Ave SE runs east through a residential area, connecting with the major north-south arteries of Deerfoot Trail and Blackfoot Trail, as well as 17th St. SW, an east-west artery, and the Baines Bridge, a small river crossing on the Zoo island. It carries around 20,000 vehicles per day.

Fig. 2: Centre Street Bridge and other major downtown area bridges



Transit service was maintained on Centre Street at all times, so there was no need for existing transit users to change routes. In addition, bus service on the Louise and Langevin Bridges, and the North East and North West LRT line transit services between downtown and the north, were available for some car users impacted by the bridge closure.

2.3. Spare Traffic Capacity on Alternative Routes

Calgary is a major city with a 2000 population of 860,000. Around 51% of this population live north of the Bow River, which forms the northern boundary of the Downtown. The Downtown area of the city is a major employment area with over 100,000 jobs. There are only a limited number of roadway bridges crossing the Bow River in the central area.

As a result these central river roadway bridge crossings and approach routes are very heavily used in peak periods, and traffic delays occur at peak times in the weekday AM and PM rush hours. 42% of Downtown workers use transit to get to work, otherwise the road system would be even more congested.

Congestion also occurs in peak hours on the transit system, with LRT trains and busses having high occupancies.

The weekday AM peak travel demand in the Downtown area lasts approximately 2 hours, from 7 AM to 9 AM. Similarly the PM peak lasts 2 hours, from 4 PM to 6 PM. Outside these times weekday travel demand levels in the Downtown are lower, and traffic currently flows relatively freely. Weekend traffic levels in the Downtown are also generally relatively light.

Table 1 gives the 1999 typical weekday peak direction AM peak hour (7:30 AM to 8:30 AM) and PM peak hour (4:45 PM to 5:45 PM) traffic flows on the central roadway bridges in the north part of the Downtown:

Table 1 1999 Peak Hour Weekday Traffic Flows on the Central Bridges

Bridge	AM Peak Hour Traffic Southbound (vehicles / hour)	PM Peak Hour Traffic Northbound (vehicles / hour)
Centre Street Upper	2,450	2,750
Centre Street Lower	950	900
Louise	2,850	1,950
Langevin	1,750	4,600*
Memorial	2,450	(* 5th Ave Flyover)

Very limited spare traffic capacity was available on the Louise, Langevin and Memorial Drive Bridges in the peak hours, with their existing operation.

Some traffic management measures were undertaken to try to optimize traffic flows during the Centre Street Bridge closure. These are described in Section 2.5 below.

Table 2 gives the 1999 typical weekday peak direction flows in the "shoulder" of the 2-hour AM peak period (i.e. 7 AM to 7.30 AM and 8.30 AM to 9 AM) and "shoulder" of the 2-hour PM peak period (i.e. 4 PM to 4.45 PM and 5.45 PM to 6 PM) on the central roadway bridges in the north part of the Downtown:

Table 2 1999 Peak Shoulder Weekday Traffic Flows on Central Bridges

Bridge	AM Peak Shoulder Traffic Southbound (vehicles / hour)	PM Peak Shoulder Traffic Northbound (vehicles / hour)
Centre Street Upper	1,850	2,250
Centre Street Lower	650	700
Louise	2,150	1,700
Langevin	1,400	3,850 *
Memorial	2,400	(* 5th Ave Flyover)

Spare traffic capacity was available on the alternative Bridges in the shoulder of the peak period, based on differences in observed flows between the peak

hour and the peak shoulder. It was estimated that in total around 1,000 to 1,100 more peak shoulder vehicles could be carried in the peak direction : 250 to 350 on the Louise Bridge; and 700 to 750 on the Memorial and Langevin Bridges.

2.4. Travel Times on Alternative Routes

Traffic using the Centre Street upper deck is mainly going to and from the residential areas in north central Calgary and Downtown (and other areas south of the Bow river). The alternative routes involve a detour either to the west (to 14th Street or 10th Street, 2.2 km and 1.5 km respectively west of Centre Street)) or to the east (to Edmonton Trail, 0.8 km east of Centre Street). For many Centre Street users there may be additional travel distances and times associated with these routes, depending upon their specific trip origin and destination.

Traffic using the Centre Street lower deck is accessing Downtown from Memorial Drive, and this traffic can use one of the other Bridges served from Memorial Drive, so there is less direct travel time and distance impact for these users from the Centre Street Bridge closure.

Extra traffic diverted from Centre Street and using these alternative routes will increase the peak traffic congestion and delays that currently occur on these routes. This will impact the travel times for both former Centre Street Bridge users and the original users of these other routes.

2.5. Traffic Management / Transit Measures

In order to minimize the impact of the Centre Street Bridge closure the City of Calgary put in place a number of measures:

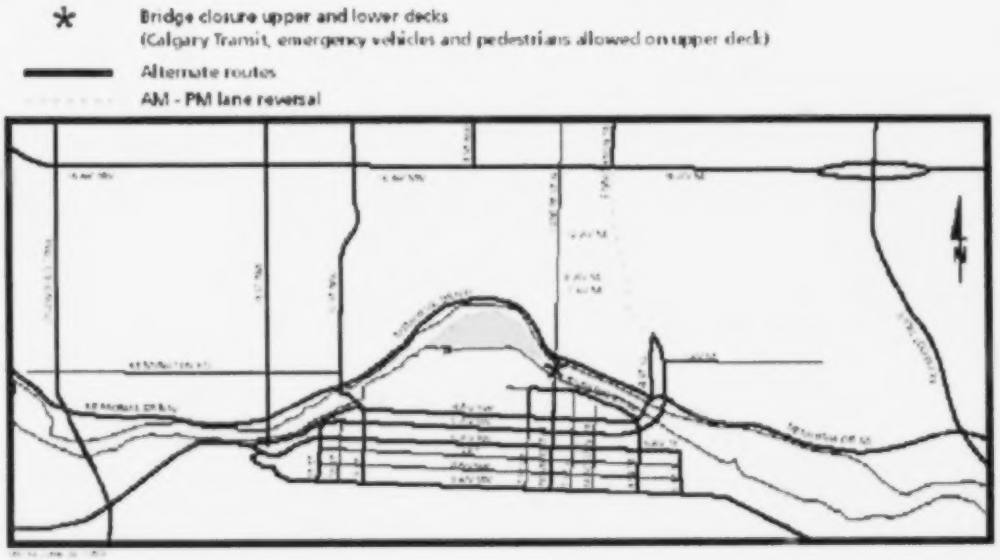
- A major publicity campaign was undertaken prior to the bridge closure advising people of the issue, and encouraging them to use alternatives such as transit, and varying their work hours.
- Transit service was maintained on Centre Street throughout the bridge closure; and additional transit service was provided connecting the north central area to Downtown.

Traffic Management changes include the following:

- Increased peak flow green time (inbound in AM peak, outbound in PM peak) at Memorial Drive/Edmonton Trail NE, Memorial Drive/10 St NW, 10 St/5 Ave NW and 4 Av/1 St SE.

- Additional turning lanes added at Memorial Drive/Edmonton Trail NE, 16 Ave/Centre St N, 5 Ave/1 St SE, 16 Ave/4 St NW and Memorial Drive/Kensington Road NW.
- Lane reversal on Edmonton Trail from 16 Ave to 2 Ave, with three lanes inbound in the AM, and three outbound in the PM.

Fig. 3: Alternate routes and traffic management measures (from City of Calgary website on Centre Street Bridge closure)


Bridge closure upper and lower decks
(Calgary Transit, emergency vehicles and pedestrians allowed on upper deck)
Alternate routes
AM - PM lane reversal

3. Centre Street Bridge Closure Survey and Report

In November / December 1999 the International Results Group (IRG), on behalf of the City of Calgary, surveyed car users of the Centre Street Bridge (who used the bridge prior to the closure) and other adjacent roadway bridges in the northern sector of the Downtown. The primary purpose of the survey was to obtain demographic and travel behaviour of car users before and during the bridge closure, to help the City of Calgary Transportation Department.

The purpose of this section is to give a brief overview of the survey.

3.1. Centre Street Bridge Closure Survey

The City of Calgary Transportation Department commissioned IRG to conduct a survey of around 1,500 users of the north bridges in the Downtown, who used the bridges prior to the Centre Street closure. A survey instrument was developed that obtained data on:

- Personal data of each traveller;
- Trip origin and destination characteristics prior to the closure;
- Frequency and type of use for related routes;
- Awareness of advertising, public service announcements and media coverage
- Whether trip was still being made regardless of the closure, and if not why not;
- Trip details for the survey day (i.e. during the closure);
- The normal travel behaviour with the bridge closed.

A copy of the survey instrument is given in Appendix A.

Between November 18th 1999 and December 23rd December IRG conducted a telephone survey on two samples:

- A data-base of 3,500 car users who used Centre Street or other north Downtown bridges prior to the bridge closure. This sample was drawn from a licence plate survey of weekday peak period private vehicles (inbound during the AM peak, outbound during the PM peak, and in either direction during the midday peak). Licence plate numbers were collected from

vehicles crossing the Centre Street Bridge, the Louise Bridge, the Langevin Bridge, the 4th Avenue flyover and the 5th Ave Flyover. Priority was given to licence plate numbers collected on more than one occasion. Contacts were screened to ensure they regularly travelled into the Downtown or out of the Downtown area before the Centre Street Bridge closure on a typical weekday. Altogether 1,099 completed surveys were obtained from this source.

- A random sample of 3,500 Calgarians listed in the latest "Reverse" telephone directory whose addresses were located in the NE and NW quadrants of the City. Altogether 253 completed surveys were obtained from this source.

In total 1,352 completed surveys were obtained. It was necessary to use the second sample because an insufficient number of successful completed surveys were obtained from the first sample.

Table 3 summarizes the survey sample by bridge used prior to the survey, and survey sample. It also gives the % of vehicles using each bridge prior to the closure that were sampled.

Table 3 Centre Street Bridge Survey Sample

Bridge	License Plate Sample	Address Sample	Total Sample	Daily Vehicles	% Vehicles Sampled
Centre Street Upper	388	92	480	25,000	1.9%
Centre Street Lower	187	17	204	9,000	2.3%
Louise Bridge	268	69	337	32,000	1.1%
Langevin	110	28	138	46,000	0.3%
Memorial Drive	146	47	193	39,000	0.5%
TOTAL SAMPLE	1,099	253	1,352	151,000	0.9%

IRG submitted a report "A Survey and Study on the Centre Street Bridge Closure", which summarized the survey method and results, in 2000.

A list of the figures, tables and tabulations contained in the IRG report is given in Appendix B.

3.2. Characteristics of the Survey Sample / Survey Data

A number of key characteristics of the survey sample, and the data collected influence the type of analysis of the results obtained. In particular:

- The survey focussed on travel on a typical weekday. Weekend travel was not considered.

- The people surveyed were by definition all car users prior to the Centre Street Bridge closure. Data on potential mode preferences for modes other than the car is only available from the travel behaviour during the closure.

The survey sample was drawn:

- from licence plates of vehicles travelling on the northern Downtown bridges into the Downtown in the AM peak on a weekday, out of the downtown in the PM peak on a weekday, and in either direction during the midday peak on a weekday; who were likely to be residents of north Calgary; and
- from residents of the NE and NW quadrants, who would also be likely to use the northern bridges to travel into Downtown. The survey sample did not capture people who lived in other parts of Calgary, who use Centre Street and the other northern Downtown Bridges to travel out of Downtown.

The survey explicitly asked details of the first and subsequent trips on a weekday made using the bridges on a typical weekday (those who made a return trip on the same route were also asked what time they made that trip, and how long it took). In practice, only 35 respondents gave information for more than one trip. As a result of the sampling method described above:

- The direction of travel of these first trips is inbound; and
- The time of day of travel of the people surveyed is heavily weighted towards the AM peak.

89% of the trips captured in the Survey were made between 6.30 and 9 AM; with 4% made prior to 6.30 AM and only 7% made after 9 AM. This contrasts with the observed pattern of southbound daily traffic flow across the northern Downtown bridges on a weekday, which shows 4% prior to 6.30 AM; 22% between 6.30 and 9 AM; and 74% after 9 AM for the rest of the day.

As a result of this AM peak period focus, the journey purpose for the trips captured in the survey is heavily weighted towards the commuter work trip, with 77% of trips being made for the Work purpose; and an additional 15% to drop someone off.

The above characteristics of the survey sample and the travel data obtained mean that significant conclusions can only be drawn about the impact on the Centre Street Bridge closure on the travel behaviour of AM peak period car users, primarily those peak period car users who are travelling to work. Insufficient data is available for much detailed analysis of car users travelling outside the AM peak period; or for other purposes than work.

On most roadways in Calgary the peak periods are the times where there is the most traffic congestion problems; and work trips comprise a significant proportion of these peak hour trips on most routes. The findings from the Survey will therefore still be of relevance in understanding how car users react to construction-related road closures.

4. Potential Travel Behaviour Changes

This section discusses the range of travel behaviour changes that vehicle users can make when roadway capacity is reduced. It is intended to define the context for analysis of the impact of the Centre Street Bridge closure.

4.1. Potential Situations Impacting Traffic Flows

The amount and type of travel behaviour change experienced with a roadway capacity reduction is dependent upon the nature and extent of the project. There are three basic situations where roadway capacity reductions can occur:

- Planned permanent roadway capacity reductions, in order to achieve other goals such as the implementation of traffic management projects e.g. pedestrianization, or new development.
- Planned temporary roadway capacity reductions, usually to accommodate construction or repair work. The period of reduction can range from short-term, lasting only a few hours or days, to longer-term, lasting months or years. The Centre Street Bridge closure falls into this category.
- Unplanned temporary roadway capacity reductions, arising from unforeseen circumstances such as accidents, structural failures e.g. water-main breaks, or natural disasters such as earthquakes. Again, the period of capacity reduction can last from short-term to long-term.

In the planned cases it is possible to minimize the impact on traffic flow, by providing advance notice to users of the facility, and maximizing the availability of roadway alternatives through signs, changes in traffic control and management, and increases in transit service. All of these measures were implemented for the Centre Street project.

The extent to which the travel behaviour of road users of an affected facility will change is dependent upon the availability of alternatives that offer similar travel conditions to those that they currently enjoy. There are basically three levels of the conditions on alternatives that will impact behaviour:

In a few situations, there is no real net roadway capacity reduction, because capacity increases on or close to the affected route, achieved by changes in traffic control and management, offset any direct reduction. In these cases

there is little or no change in overall traffic flows, congestion, or traveller choice.

In some situations there is a real net reduction in capacity on the affected corridor, but it is not a deterrent because these alternative routes are readily available, and generally have sufficient spare capacity to absorb any diverted traffic.

In these situations, traffic does decrease in the specific place or time where it would experience delays, but it reappears on the other routes and / or at some other time.

Car users therefore change their route or their specific time of travel to a limited degree, but the overall number and pattern of vehicle trips is not significantly affected.

In some situations there is a significant reduction in roadway capacity in a corridor, and there is not sufficient spare capacity on readily alternative routes at the preferred time of travel to absorb the diverted traffic, because of the existing levels of traffic. In these situations, as well as changing routes and travel times, car users may have to make more significant travel behaviour changes, including changing travel mode, trip destination, or trip frequency.

The Centre Street Bridge closure created travel situations that fell into the second and third categories above. At peak travel times the alternative routes had insufficient capacity to cope with all the traffic normally using Centre Street. At other times of day, and on weekends, there was generally sufficient spare capacity on the other routes to be able to handle any traffic diverted from Centre Street without significantly increasing travel delays on those routes.

4.2. Potential Travel Behaviour Changes

The following potential changes in individual car user travel behaviour can occur as a direct result of situations where roadway capacity has been reduced:

- Changes in driving style that increase roadway capacity (travelling faster, following more closely, accepting shorter gaps)
- Changes in route
- Changes in time at which trips are made
- Changes in mode of travel
- Changes in trip origin or destination

- Consolidation of trips to serve several destinations on one journey (trip chaining)
- Trip elimination

As mentioned above, the scale of behaviour change will depend upon the nature and extent of the roadway capacity reduction. It is also dependent upon the unique circumstances of each individual traveller. Each person has their own reasons and needs to make any particular trip, and has their own range of alternative choices that are feasible.

For example, there may be less flexibility to change the trip travel time or destination for trips to work than for a trip to a restaurant. Car drivers who have to drop their children off at a day-care before continuing on to their work may have little real choice for their mode of travel.

4.3. Changes in Travel Behaviour over Time

Studies of the effect of roadway capacity reductions on travel behaviour have shown that the following time-related reactions tend to take place:

Immediately following the capacity reduction, there is a period of instability in traffic patterns as drivers react to the change. Peak traffic congestion can increase significantly on alternative routes as drivers divert to them. There is a period of adjustment necessary as all vehicle users in the affected areas make decisions as to their route and time of travel choice, or make even larger travel behaviour decisions such as to change mode or destination. However, after only a few days a new "equilibrium" travel pattern emerges where there is relative stability.

One of the theoretical principles of equilibrium in a congested network is that the travel time on all available routes from one point to another should be similar. When an existing traffic equilibrium is upset because of a major capacity reduction, traffic re-distributes itself as drivers search for their new "best" route. Experience shows that a stable new pattern is generally found surprisingly quickly. In this new traffic pattern, travel times at peak times may be somewhat longer than before, but do not reach unacceptable levels, because these would generate travel behaviour changes.

In some cases, good advance warning about a proposed capacity reduction, and good provision of alternatives where they are available, may produce the situation where drivers react so logically to the change that little disruption occurs even on the first day.

In the medium term, up to perhaps a year or so of a capacity reduction, there is a settled period. Traffic has adapted to the new conditions, and although there are daily and seasonal variations traffic conditions are normal and predictable.

In the longer term, trend growth in traffic occurring in the area may cause traffic conditions in the area to deteriorate. Conversely, transportation policies that affect travel demand in the area as a whole might cause conditions to improve. Both these sets of impacts occur as a result of changes beyond the scope of the roadway capacity reduction itself.

4.4. Changes in Users of Facilities over Time

It is important to recognize that traffic patterns are not static. People do not make the same trips by the same mode on the same routes at the same times of day, for ever. People continually are changing because of demographic and socio-economic circumstances. They age, change their employment status (e.g. from student to worker), marry, have children, change their job, buy a new home, buy a new car, and so on. Each of these changes can significantly alter their travel patterns. The scale of such changes is often under-estimated.

This phenomenon of changing travel patterns is particularly relevant when considering the effects of traveller responses to changes in roadway capacity reductions. In general there are three distinct traveller markets to be considered when looking at "before" and "after" travel patterns:

- A stable set of individuals using transportation facilities in the affected area both before and after the capacity reduction, whose external circumstances have not changed, and who have the same personal travel choice constraints after the closure as they did before. Changes in these individuals' behaviour captured in "before" and "after" surveys may be attributed directly to the capacity reduction itself.
- A set of individuals using roadway facilities in the affected area before the capacity reduction, whose external circumstances have changed. They no longer have the same travel choices; and may not even continue to travel in the affected area. Their changes in travel behaviour may directly impact the amount of travel in the affected area, but cannot be attributed to the capacity reduction itself.
- A set of individuals not using roadway facilities in the affected area before the capacity reduction, whose external circumstances have changed. They no longer have the same travel choices; and after the capacity reduction now travel in the affected area. Their changes in travel behaviour may directly impact the amount of travel in the affected area, but cannot be attributed to the capacity reduction itself.

The Centre Street Bridge Closure Survey only surveyed those car users who used the northern Downtown bridges before the bridge closure. The third category of individual, who only used the bridges after the closure, were not captured in the survey.

5. Findings of Other Studies

This section describes the results of other studies that have examined the effect of changes in roadway capacity changes on traffic flows. It is noted that these studies have concentrated on looking at the changes in vehicle traffic levels i.e. they have not examined changes in personal travel by all modes.

5.1. Measured Changes in Traffic Levels

Goodwin et al (1998) summarized the empirical results from over 100 studies around the world documenting changes in traffic flows arising from roadway capacity reductions. These studies included all three of the circumstances for capacity reduction outlined in Section 4.1 above (planned permanent reductions; planned temporary reductions; and unplanned temporary reductions).

A wide range of changes in traffic volumes were found. It was pointed out that the individual circumstances behind each situation had to be understood before the particular results could be interpreted. However, in the majority of studies a reduction in traffic flow was observed. On average it was found that there was a net 15% decrease in daily traffic flows in the area occurring as a result of roadway capacity reductions.

Goodwin (1998) lists the individual results for a number of locations for temporary bridge closures / major capacity reductions. Table 4 shows these bridge locations, date and length of closure, daily traffic flow carried prior to the closure, net change in traffic in the area, and net % change in daily traffic in the area.

Table 4 Observed Changes in Traffic Flow for Bridge Closures / Major Capacity Reductions

Bridge	Date & Length Closure	Daily Traffic Flow	Change in Daily Traffic in Area	% Change in Daily Traffic in Area
Hobart, Australia	1975, 14 months	44,000	-27,000	-61%
Tower Bridge, London	1993, 1 month	44,000	-35,000	-24%
Kinnaird Bridge, Edmonton	1979, 3 weeks	1,300 peak hour	-550 peak hour	-16%
Hammersmith Bridge, London	1997, 1 month	31,000	-10,000	-8%
York, England	1978/9, 1 month	16,000	-3,000	-4%
Munich, Germany	1988	32,000	0	0%
Frankfurt, Germany	1989	29,500	500	+0.3%

Note: Edmonton data is for peak hour peak direction of travel

This table shows the range of traffic flow changes that have been found with bridge closures. The Hobart situation involves a major bridge collapse with limited alternative capacity, which explains the high reduction found there.

The Tower Bridge, London case only measured traffic flows on the four bridges leading to the City of London, and may not have captured all the traffic diversions to other routes that took place.

5.2. Data Collection / Measurement Issues

Goodwin (1998) noted that there were a wide variety of methods of collecting data on observed changes in traffic flow arising from roadway capacity reductions. These included traffic counts, roadside interviews, personal travel surveys, and ongoing panel surveys.

Each of these survey methods contained some form of potential systematic bias, that could influence the results obtained. Four main types of potential survey bias were identified:

One-day traffic counts do not allow for the day to day or seasonal variability that occurs in practice in traffic flows. "Before" and "After" comparisons made using one-day counts may contain these "natural" variations in flow, that would mask the true impact of the capacity reduction.

Journey detours may extend over a larger distance than that captured in screen-line or cordon counts. In these cases the "Before" and "After" survey results will over-state the true net negative impact on traffic flows that result from a capacity reduction, as some diverted traffic is simply not counted.

Traffic growth occurs due to other factors such as population and employment growth, increased income and car ownership. In these cases the "Before" and "After" survey results will under-state the true net negative impact on traffic flows that result from a capacity reduction, as this "natural" traffic growth is included in the "After" survey.

There may be only partial sampling of all the people affected by the capacity reduction. If a survey-based study is confined exclusively to the users of the affected corridor prior to the reduction, it can observe people who reduce their use, but will not observe offsetting former non-users who increase their use, resulting in an over-estimate of the true reduction in travel that occurred.

All of the above issues may exist with the data being used to assess the impact of the Centre Street Bridge closure. The observed traffic and transit count data is based on one-day counts; the area of impact is defined as the northern bridges on the Downtown boundary; the observed count data for "before" and "after" is measured one year apart, in May 1999 and May 2000; and the telephone survey was limited to those who used the bridges prior to the closure.

Some of these concerns may be able to be addressed in the analysis e.g. by looking at general traffic growth trends in traffic to Downtown Calgary in 1999. However the results will have to be interpreted with some caution.

6. Changes in Observed Traffic and Transit Flows

This section describes the analysis of the changes in observed traffic and transit flows that occurred during the closure of the Centre Street Bridge.

Every year during May on typical weekdays the City of Calgary conducts "cordon" counts for traffic and transit passenger flows on roadways and transit facilities entering and leaving the Downtown. While these counts take place over the first three weeks of the month, they are usually conducted on the same day for a given facility; for example, a count is conducted on 9 Ave E on the second Tuesday of the month. These counts are conducted for one day on each facility from 7 AM to 11 PM, and include vehicle occupancy counts. Vehicle flows, vehicle passenger flows, and transit passenger flows in and out of the Downtown can thus be compared for May 1999, prior to the Centre Bridge closure, and May 2000, during the Bridge closure. An automatic count over a 24 hour period is also done at about the same time; these counts only count the number of vehicles and do not provide a breakdown of passengers, pedestrians or vehicle types.

Data can be tabulated both for roadways and transit facilities on the northern boundary of Downtown, where the impact of the bridge closure is expected to be seen; and also for the transportation facilities on the southern boundary of the Downtown. Flows on these southern facilities are not expected to be affected significantly by the bridge closure. They can therefore serve as a "control" source of information for the underlying shift in travel patterns to and from the Downtown that occurred between May 1999 and May 2000. Additionally, there are two routes (Bow Trail and 9 Ave E) that run east-west into the downtown; Bow Trail from the west and 9 Ave from the east. These routes do head into communities to the east and west, but they also intersect major north-south routes (Crowchild Trail and Deerfoot Trail via Blackfoot Trail respectively) and would be expected to be moderately affected by the closure, with traffic from the east/west and south acting as a buffer to reduce any changes that result from the closure.

6.1. Automatic 24-Hour Count Data

This data was obtained from 24-hour automatic counters, which results in a total vehicle count only, with no information on the number of occupants, transit passenger flow or total person flow.

There are other limitations with this data; due to the large amount of data, traffic flows were only analysed on the three most heavily travelled southern routes (8th St W, 4th St W and MacLeod Trail), which, according to the 16-hour manual screenline counts, carry 78% of the southern vehicle flows. Also, only inbound traffic was analysed. Thirdly, counts were unavailable for the lower deck of the Centre Street Bridge. Additionally, there was a failure with the equipment used in counting the vehicle flows on the Louise Bridge in 2000. This is a significant loss of data.

To compensate for this lost data, values of traffic flows for a 'pseudo' Louise bridge were created by multiplying the change in traffic flow volumes between 1999 and 2000 for parallel routes by the value in traffic flows for the Louise bridge for the given period. The parallel routes used were the Langevin Bridge, the 4th Avenue Flyover and the 14th Street southbound connector to 9th Avenue. The change in flows on these routes was found in a weighted manner; in other words, to get a change value the total 2000 volumes were divided by the total 1999 volumes. The equation used for this was the following:

$$V_{Louise} = v_{Louise} \cdot \frac{V_{Langevin} + V_{Flyover} + V_{14thSt}}{v_{Langevin} + v_{Flyover} + v_{14thSt}}$$

where V_{bridge} represents the 2000 traffic flow for a given period for a bridge, and v_{bridge} represents the 1999 traffic flow.

As an example, to calculate a value for the 2000 traffic flow from 4 AM to 5 AM on the Louise bridge, the following data is used:

- Louise volumes: 19 in 1999, unknown in 2000.
- Langevin volumes: 70 in 1999, 91 in 2000.
- 4th Ave Flyover volumes: 88 in 1999, 146 in 2000.
- 14th Street volumes: 18 in 1999, 13 in 2000.

Therefore:

$$V_{Louise} = 19 \cdot \frac{91+146+13}{70+88+18} = 26.9886 \approx 27$$ vehicles in 2000.

A similar calculation was made for the lower deck of the Centre Street Bridge, extrapolating traffic as a percent of the upper deck of the Centre Street Bridge, based on 16-hour inbound count data. The traffic was taken as 0 during the closure, however, because the lower deck was physically inaccessible, whereas the upper deck was restricted to transit and emergency vehicles.

Table 5 shows both the vehicle flows and the changes in inbound vehicle flows for the 2000-1999 period on the north routes, as well as the east-west routes and three south routes, as measured over an entire 24-hour period.

Table 5 Inbound Vehicle Flows and Changes, 24 hour periods

Bridge	1999 Vehicles	2000 Vehicles	2000 – 1999 Vehicles	2000 - 1999 Change (%)
Centre Street Upper	12929	407	-12522	-96.9%
Centre Street Lower (extrapolated)	4009	0	-4009	-100%
Louise Bridge (including extrapolated data)	15152	16958	1806	11.9%
4th Ave Flyover	29438	29699	261	0.9%
Langevin	16109	20922	4883	30.3%
14th Street North accesses	6120	7135	1015	16.6%
Total North routes	83756	75191	-8565	-10.2%
Total North routes (excluding Louise)	68605	58233	-10372	-15.1%
Bow Trail	25148	27218	2070	8.2%
9th Ave E	8279	9640	1361	16.4%
South routes (8th St, 4th St, MacLeod)	53163	50443	-2720	-5.1%

There was an increase in traffic on all north routes, with the obvious exception of the Centre Street Bridge. On the other hand, south routes had a slight decline in traffic. In contrast, there were increases in traffic on the east and west routes of 9 Ave E and Bow Trail, which seems to suggest that Centre Street Bridge traffic may have shifted to these routes in addition to the other north routes. The overall 24-hour decline on north routes (including the extrapolated Louise data) was a decline of 10.2%, which is a greater decline than the 5.1% decline found on the south routes. The same general pattern is found with the Louise removed from the data, although there is a larger decline.

One of the limitations in the screenline count data was the late start for the morning counts; the counts started at 7 AM. The 24-hour data provides useful information on what happened before the counts started. Table 6 shows both the vehicle flows and the changes in inbound vehicle flows for the 2000-1999 period on the north routes, as well as the east-west routes and three south routes, as measured in the two-hour 'Pre-shoulder' period, from 5:00 AM to 7:00 AM.

Table 6 Inbound Vehicle Flows and Changes, Pre-shoulder (5:00-7:00 AM)

Bridge	1999 Vehicles	2000 Vehicles	2000 – 1999 Vehicles	2000 – 1999 Change (%)
Centre Street Upper	824	41	-783	-95.0%
Centre Street Lower (extrapolated)	255	0	-255	-100%
Louise Bridge (including extrapolated data)	1067	2388	1321	123.8%
4th Ave Flyover	518	2398	1880	362.9%
Langevin	1035	1505	470	45.4%
14th Street North accesses	403	474	71	17.6%
Total North routes	4102	6806	2703	65.9%
Total North routes (excluding Louise)	3035	4418	1382	45.5%
Bow Trail	2205	2610	405	18.4%
9th Ave E	411	412	1	0.2%
South routes (8th St, 4th St, MacLeod)	2034	2184	150	7.4%

It is obvious from these numbers that there was a very significant increase in traffic in the pre-shoulder period, with even a net gain for north routes despite the closure of the Centre Street Bridge. This is contrasted with a much smaller gain on the south routes. The same volume of traffic existed on 9th Ave E, but Bow Trail had a significant increase in traffic.

If the 'pseudo-Louise' bridge data is removed, and the parallel routes alone are used, there is still a very significant increase in traffic for the north routes.

6.2. Manual AM Peak Hour Counts

In addition to the 24-hour automatic vehicle data, there was a downtown cordon study done involving manual counts around a downtown cordon that included the north, east/west and south screenlines used in this study. This manual count included LRT lines as well as, for the year 2000, pedestrian-only bridges. Information gathered by the manual count included counts of both vehicles and occupants for cars, trucks, Calgary Transit vehicles and other buses, as well as pedestrians and cyclists.

Unfortunately, this manual count began at 7:00 AM, which, based on the 24-hour vehicle counts, is missing data during the shifted peak seen in the 2000 data for the north routes. However, this manual count has excellent mode choice information, and can be used to evaluate potential mode shifts.

The following sections describe observed changes in flows between a weekday in May 1999 and May 2000 for the following time periods:

- AM Peak Hour (7:15 AM to 8:15 AM)
- AM Peak Shoulder (7:00 to 7:15 AM & 8:15 to 9:00 AM)
- PM Peak Hour (4:45 PM to 5:45 PM)
- PM Peak Shoulder (4:00 to 4:45 PM & 5:45 to 6:00 PM)
- 16-Hour (7:00 AM to 11:00 PM)

Table 7 gives the May 1999 and May 2000 weekday flows by mode across the northern Downtown bridges in the AM peak hour (7:30 AM to 8:30 AM), in the southbound direction:

Table 7 May 1999 and May 2000 Weekday AM Peak Hour Inbound Flows by Mode

Bridge	May 1999 Vehicle	May 1999 Auto Occu-pants	May 1999 Transit Pass-engers	May 1999 Total Persons	May 2000 Vehicle	May 2000 Auto Occu-pants	May 2000 Transit Pass-engers	May 2000 Total Persons
Centre Street Upper	2055	2613	1668	4293	40	0	1888	1888
Centre Street Lower	944	1222	0	1224	0	0	0	0
Louise Bridge	2540	3050	738	3819	2615	3246	789	4040
Langevin	1778	2132	502	2759	2298	2769	457	3282
4th Ave Flyover	2467	3095	0	3304	2473	3037	0	3123
14th Street North accesses	1109	1432	101	1533	1244	1457	125	1554
Northeast LRT	10	0	3453	3453	11	0	3403	3403
Northwest LRT	6	0	2756	2756	7	0	3011	3011
Total	10909	13544	9218	23141	8688	10509	9673	20301

Table 8 gives the differences in AM peak hour flows between May 2000 and May 1999:

Table 8 Difference in May 2000 and May 1999 Weekday AM Peak Hour Inbound Flows by Mode

Bridge	2000 - 1999 Vehicles	2000 – 1999 Auto Occupants	2000 – 1999 Transit Passengers	2000 - 1999 Total Persons
Centre Street Upper	-2015	-2613	220	-2405
Centre Street Lower	-944	-1222	0	-1224
Louise	75	196	51	221
Langevin	520	637	-45	523
4th Ave Flyover	6	-58	0	-181
14th Street North accesses	135	25	24	21
Northeast LRT	1	0	-50	-50
Northwest LRT	1	0	255	255
Total Difference	-2221	-3035	455	-2840
% Total Difference	-20.4%	-22.4%	4.9%	-12.3%

It can be seen for AM peak hour flows southbound across the bridge screen-line:

- Total vehicle flow has decreased by 20.4%;
- Total auto occupant flow has decreased by 22.4%;
- Total transit passenger has increased by 4.9%;
- Total person flow has decreased by 12.3%.

i.e. total AM peak hour vehicle flow and total person flow across the bridge screen-line have both decreased overall, in spite of increases in vehicle and auto occupant flows on the alternative routes; and increases in transit flows on the Centre Street and other routes.

In contrast, AM peak hour weekday flows northbound across the "control" southern Downtown screen-line (defined to encompass roads and transit routes between 14 Street W through 7 Street E) changed by the following percentages between May 1999 and May 2000:

- Total vehicle flow has decreased by 1.0%;
- Total auto occupant flow has increased by 1.7%;
- Total transit passenger flow has increased by 5.6%;
- Total person flow has increased by 2.7%.

To the west, Bow Trail had a general decline in peak hour usage:

- Total vehicle flow has decreased by 1.9%;
- Total auto occupant flow has decreased by 4.3%;
- Total transit passenger flow has decreased by 0.4%;

- Total person flow has decreased by 2.8%.

To the east, however, 9th Avenue SE had a marked increase in peak hour usage:

- Total vehicle flow has increased by 22.0%;
- Total auto occupant flow has increased by 21.4%;
- Total transit passenger flow has increased by 39.2%;
- Total person flow has increased by 26.8%.

In general, then, north routes had an overall decline in peak hour use, although use generally rose on routes other than the closed Centre Street Bridge. South routes had a marginal increase in use, and Bow Trail had a slight decrease. 9th Avenue SE had a significant increase in peak hour use.

Transit use increased in the AM peak on both north and south routes by a similar amount; it followed the trends of the rest of the flows on Bow Trail and 9th Avenue, decreasing marginally on the former and increasing significantly on the latter.

6.3. Manual AM Peak Shoulder Counts

Table 9 gives the May 1999 and May 2000 weekday flows by mode across the northern Downtown bridges in the AM peak shoulder (7.00 to 7.15 AM and 8.15 to 9.00AM), in the peak southbound direction:

Table 9 May 1999 and May 2000 Weekday AM Peak Shoulder Inbound Flows by Mode

Bridge	May 1999 Vehicle	May 1999 Auto Occu-pants	May 1999 Transit Pass-engers	May 1999 Total Persons	May 2000 Vehicle	May 2000 Auto Occu-pants	May 2000 Transit Pass-engers	May 2000 Total Persons
Centre Street Upper	1474	1863	1653	3526	50	0	1606	1606
Centre Street Lower	609	768	0	769	0	0	0	0
Louise Bridge	1868	2286	584	2896	2231	2756	413	3200
Langevin	1424	1728	315	2085	2176	2590	239	2965
4th Ave Flyover	2421	2943	0	3016	2508	3089	0	3178
14th Street North accesses	792	1010	60	1077	945	1150	25	1225
Northeast LRT	9	0	2589	2589	8	0	2905	2905
Northwest LRT	13	0	1912	1912	32	0	2941	2941
Total	8610	10598	7113	17869	7950	9585	8129	18020

Table 10 gives the differences in AM peak shoulder flows between May 2000 and May 1999:

Table 10 Difference in May 2000 and May 1999 Weekday AM Peak Shoulder Inbound Flows by Mode

Bridge	2000 - 1999 Vehicles	2000 – 1999 Auto Occupants	2000 – 1999 Transit Passengers	2000 - 1999 Total Persons
Centre Street Upper	-1424	-1863	-47	-1920
Centre Street Lower	-609	-768	0	-768
Louise	363	470	-171	304
Langevin	752	862	-76	880
4th Ave Flyover	87	146	0	162
14th Street North accesses	153	140	-35	148
Northeast LRT	-1	0	316	316
Northwest LRT	19	0	1029	1029
Total Difference	-660	-1013	1016	151
% Total Difference	-7.7%	-9.6%	14.3%	0.8%

It can be seen for AM peak shoulder flows southbound across the bridge screen-line:

- Total vehicle flow has decreased by 7.7%;
- Total auto occupant flow has decreased by 9.6%;
- Total transit passenger has increased by 14.3%;
- Total person flow has increased by 0.8%.

i.e. total AM peak shoulder vehicle flow and total person flow across the bridge screen-line have both decreased overall, in spite of increases in vehicle and auto occupant flows on the alternative routes; and increases in transit flows on the Centre Street and other routes.

In contrast, AM peak shoulder weekday flows northbound across the "control" southern Downtown screen-line defined to encompass roads and transit routes between 14 Street W through 7 Street E) changed by the following percentages between May 1999 and May 2000:

- Total vehicle flow has decreased by 0.5%;
- Total auto occupant flow has decreased by 0.3%;
- Total transit passenger has increased by 22.9%;
- Total person flow has increased by 9.3%.

Bow Trail to the west had a small increase in AM shoulder vehicles and auto occupants (up 5.1% and 5.7%, respectively), with a significant decrease in transit passengers (down 20.3%) leading to a slight (-1.4%) decline in total AM shoulder person flow.

To the east, 9th Ave SE had major increases in AM shoulder vehicles and auto occupants, up 24.8% and 26.2% respectively. There was a slight decline in transit use (-4.2%), with the resulting total person flow up 11.7%.

6.4. Manual AM Peak Period Counts

In addition to the transit and auto users, counts were done on metabolic forms of transportation; namely, walking and cycling. Unfortunately, counts on three metabolic-only bridges (Prince's Island Park Bridge, St. George's Island Bridge and the lower deck of the Northwest LRT Bridge), all of which enter downtown from the north, were not done in 1999. The results for the counts of metabolic transportation from 7 AM to 9 AM are summarised in table 11.

Table 11 Difference in May 2000 and May 1999 Weekday AM Peak Period Inbound Flows by Metabolic Mode

Route	1999 Cycle	1999 Walk	2000 Cycle	2000 Walk	1999 Total	2000 Total	% Change
North (excluding Prince's Island, St. George's, NW LRT bridges)	155	1122	153	1206	1277	1359	6.4%
East/West routes	512	134	556	129	646	685	6.0%
South Routes	367	3340	414	3221	3707	3635	-1.9%
Total	1034	4596	1123	4556	5630	5679	0.9%

It can be seen that while on the control routes to the south, there was a general decline in use of metabolic modes of transportation, in contrast to 6.0% and 6.4% increases on the east/west and north routes, respectively.

The three north bridges missing data (Prince's Island, St. George's Island and Northwest LRT) had 1185 pedestrians and 394 cyclists in 2000, a total of 1579 persons. This represents 53.7% of metabolic traffic from the North. If the 6.4% increase in use is assumed to have occurred with these three bridges, a total of 2761 persons would have used metabolic modes of transportation, 177 fewer than the 2938 that were recorded in 2000.

Looking at vehicle occupancy in the two-hour AM peak period, along north routes the total number of cars in the AM peak declined from 19053 to 16186 during the bridge closure. The total number of cars that crossed the screenline across the south routes in the AM peak also declined during the bridge closure, with 1999 volume of 10063 and 2000 volume of 9972.

These declines resulted in minor changes in occupancy. Along the north routes, average occupancy declined from 1.267 people per vehicle in 1999 to 1.241 in 2000; on the other hand, across south routes, occupancy increased from 1.206 to 1.229 people per vehicle. These trends represent a 2.0% decline in the north and a 1.9% increase in the south.

6.5. Manual PM Peak Hour Counts

Table 12 gives the May 1999 and May 2000 weekday flows by mode across the northern Downtown bridges in the PM peak hour (4:45 PM to 5:45 PM), in the peak northbound direction:

Table 12 May 1999 and May 2000 Weekday PM Peak Hour Outbound Flows by Mode

Bridge	May 1999 Vehicle	May 1999 Auto Occ-upants	May 1999 Transit Pass-engers	May 1999 Total Persons	May 2000 Vehicle	May 2000 Auto Occ-upants	May 2000 Transit Pass-engers	May 2000 Total Persons
Centre Street Upper	2138	2794	1601	4768	51	0	1854	1934
Centre Street Lower	913	1193	0	1193	0	0	0	0
Louise Bridge	1425	1863	853	2728	1770	2300	643	2952
5th Ave Flyover	4605	5582	399	6119	4838	6156	923	7212
14th Street North accesses	859	1109	125	1261	983	1282	110	1397
Northeast LRT	10	0	3188	3188	10	0	3591	3591
Northwest LRT	9	0	2960	2960	12	0	2916	2916
Total	9959	12541	9126	22217	7664	9738	10037	20002

Table 13 gives the differences in PM peak hour flows between May 2000 and May 1999:

Table 13 Difference in May 2000 and May 1999 Weekday PM Peak Hour Outbound Flows by Mode

Bridge	2000 - 1999 Vehicles	2000 – 1999 Auto Occupants	2000 – 1999 Transit Passengers	2000 - 1999 Total Persons
Centre Street Upper	-2087	-2794	253	-2834
Centre Street Lower	-913	-1193	0	-1193
Louise	345	437	-210	224
5th Ave Flyover	233	574	524	1093
14th Street North accesses	124	173	-15	136
Northeast LRT	0	0	403	403
Northwest LRT	3	0	-44	-44
Total Difference	-2295	-2803	911	-2215
% Total Difference	-23.0%	-22.4%	10.0%	-10.0%

It can be seen for PM peak hour flows southbound across the bridge screen-line:

- Total vehicle flow has decreased by 23.0%;

- Total auto occupant flow has decreased by 22.4%;
- Total transit passenger has increased by 10.0%;
- Total person flow has decreased by 10.0%.

i.e. total PM peak hour vehicle flow and total person flow across the bridge screen-line have both decreased overall, in spite of increases in vehicle and auto occupant flows on the alternative routes; and increases in transit flows on the Centre Street Bridge and other routes.

In contrast, PM peak hour weekday flows southbound across the "control" southern Downtown screen-line (defined to encompass roads and transit routes between 14 Street W through 7 Street E) changed by the following percentages between May 1999 and May 2000:

- Total vehicle flow has decreased by 3.8%;
- Total auto occupant flow has decreased by 2.3%;
- Total transit passenger has decreased by 0.9%;
- Total person flow has decreased by 1.3%.

Bow Trail had similarly small changes in flows, with vehicle and auto occupant flows changing –4.6% and -2.0% respectively. Transit was up slightly, 5.6%, for a total person flow change of only –0.8%.

9th Avenue E had major increases, in contrast. Vehicle and auto occupant flows were up 41.0% and 28.3% respectively. Transit passenger flow increased 110.5%, leading to a 42.6% increase in total person flows.

6.6. Manual PM Peak Shoulder Counts

Table 14 gives the May 1999 and May 2000 weekday flows by mode across the northern Downtown bridges in the PM peak shoulder (4:00 to 4:45 PM and 5:45 to 6:00 PM), in the peak northbound direction:

Table 14 May 1999 and May 2000 Weekday PM Peak Shoulder Outbound Flows by Mode

Bridge	May 1999 Vehicle	May 1999 Auto Occu-pants	May 1999 Transit Pass-engers	May 1999 Total Persons	May 2000 Vehicle	May 2000 Auto Occu-pants	May 2000 Transit Pass-engers	May 2000 Total Persons
Centre Street Upper	1606	2065	1381	3206	35	0	1204	1244
Centre Street Lower	720	982	0	985	0	0	0	0
Louise Bridge	1158	1483	495	1983	1576	2007	432	2447
5th Ave Flyover	3858	4650	272	5086	4540	5711	275	6157
14th Street North accesses	676	836	75	921	781	985	47	1041
Northeast LRT	9	0	2833	2833	7	0	2298	2298
Northwest LRT	10	0	1684	1684	8	0	2569	2569
Total	8037	10016	6740	16698	6947	8703	6825	15756

Table 15 gives the differences in PM peak shoulder flows between May 2000 and May 1999:

Table 15 Difference in May 2000 and May 1999 Weekday PM Peak Shoulder Outbound Flows by Mode

Bridge	2000 - 1999 Vehicles	2000 – 1999 Auto Occupants	2000 – 1999 Transit Passengers	2000 - 1999 Total Persons
Centre Street Upper	-1571	-2065	-177	-1962
Centre Street Lower	-720	-982	0	-985
Louise	418	524	-63	464
5th Ave Flyover	682	1061	3	1071
14th Street North accesses	105	149	-28	120
Northeast LRT	-2	0	-535	-535
Northwest LRT	-2	0	885	885
Total Difference	-1090	-1313	85	-942
% Total Difference	-13.6%	-13.1%	1.3%	-5.6%

It can be seen for PM peak shoulder flows southbound across the bridge screen-line:

- Total vehicle flow has decreased by 13.6%;

- Total auto occupant flow has decreased by 13.1%;
- Total transit passenger has increased by 1.3%;
- Total person flow has decreased by 5.6%.

i.e. total PM peak shoulder vehicle flow and total person flow across the bridge screen-line have both decreased overall, in spite of increases in vehicle and auto occupant flows on the alternative routes; and increases in transit flows on the Centre Street and other routes.

In contrast, PM peak shoulder weekday flows southbound across the "control" southern Downtown screen (defined to encompass roads and transit routes between 14 Street W through 7 Street E) changed by the following percentages between May 1999 and May 2000:

- Total vehicle flow has decreased by 1.2%;
- Total auto occupant flow has decreased by 0.3%;
- Total transit passenger has decreased by 4.4%;
- Total person flow has decreased by 1.8%.

On Bow Trail, PM shoulder vehicle and auto occupant flows increased slightly, up 4.2% and 4.2% respectively. This was offset by a 26.4% decrease in transit passengers, leading to a net person flow reduction by 5.5%.

On the other hand, there was a major, across-the-board increase in traffic on 9th Avenue SE. Vehicle and auto occupant flows increased by 35.7% and 28.6%, respectively, with transit passengers up 53.6%, creating total person flows that were 35.1% higher in 2000 compared with 1999.

Considering occupancy across the 2-hour PM peak period, including both peak and shoulder, along north routes the total number of cars in the PM peak declined from 18225 to 14221 during the bridge closure. The total number of cars that crossed the screenline across the south routes in the PM peak also declined during the bridge closure, with 1999 volume of 11910 and 2000 volume of 11521.

These declines resulted in minor changes in occupancy. Along the north routes, average occupancy increased from 1.279 people per vehicle in 1999 to 1.297 in 2000. Across south routes, occupancy also increased from 1.216 to 1.240 people per vehicle. These trends represent a 1.4% increase in the north and a 1.9% increase in the south.

6.7. Manual Inbound 16-Hour Conuts

Table 16 gives the May 1999 and May 2000 weekday 16-hour (7:00 AM to 11:00 PM) flows by mode across the northern Downtown bridges for the inbound direction:

Table 16 May 1999 and May 2000 Weekday 16-Hour Inbound Flows by Mode

Bridge	May 1999 Vehicle	May 1999 Auto Occu-pants	May 1999 Transit Pass-engers	May 1999 Total Persons	May 2000 Vehicle	May 2000 Auto Occu-pants	May 2000 Transit Pass-engers	May 2000 Total Persons
Centre Street Upper	12311	16592	6624	23746	237	0	5965	5965
Centre Street Lower	3817	4933	0	4941	0	0	0	0
Louise Bridge	12487	15252	2754	18241	14118	17628	2456	20459
Langevin	14758	17989	1828	20770	19146	23443	1695	25981
4th Ave Flyover	26569	32968	0	35030	26005	32406	0	33282
14th Street North accesses	5517	6856	422	7415	6207	7447	467	8464
Northeast LRT	90	0	13192	13192	90	0	14467	14467
Northwest LRT	96	0	10016	10016	101	0	10739	10739
Total	75645	94590	34836	133351	65904	80924	35789	119357

Table 17 gives the differences in 16-hour (7:00 AM to 11:00 PM) flows between May 2000 and May 1999:

Table 17 Difference in May 2000 and May 1999 Weekday 16-Hour Inbound Flows by Mode

Bridge	2000 - 1999 Vehicles	2000 – 1999 Auto Occupants	2000 – 1999 Transit Passengers	2000 - 1999 Total Persons
Centre Street Upper	-12074	-16592	-659	-17781
Centre Street Lower	-3817	-4933	0	-4941
Louise Bridge	1631	2376	-298	2218
Langevin	4388	5454	-133	5211
4th Ave Flyover	-564	-562	0	-1748
14th Street North accesses	690	591	45	1049
Northeast LRT	0	0	1275	1275
Northwest LRT	5	0	723	723
Total Difference	-9741	-13666	953	-13994
% Total Difference	-12.9%	-14.4%	2.7%	-10.5%

It can be seen for daily flows across the bridge screen-line:

- Total vehicle flow has decreased by 12.9%;
- Total auto occupant flow has decreased by 14.4%;
- Total transit passenger has increased by 2.7%;
- Total person flow has decreased by 10.5%.

i.e. total daily vehicle flow and total person flow across the bridge screen-line have both decreased overall, in spite of increases in vehicle and auto occupant flows on the alternative routes; and increases in transit flows on the Centre Street and other routes.

In contrast, daily weekday flows across the "control" southern Downtown screen-line (defined to encompass roads and transit routes between 14 Street W through 7 Street E) changed by the following percentages between May 1999 and May 2000:

- Total vehicle flow has decreased by 4.7%;
- Total auto occupant flow has decreased by 6.4%;
- Total transit passenger has increased by 12.2%;
- Total person flow has decreased by 2.6%.

On Bow Trail, vehicle and auto occupant flows increased slightly, by 3.4% and 1.7% respectively. Transit passenger flow was down 10.7%, leading to a total person flow decrease of 0.3%.

There was a more broad increase on 9th Avenue E, with increases of 7.2% and 8.7% for vehicle and auto occupant flows respectively, a transit passenger flow increase of 6.5% and a net overall total person flow increase of 7.6%.

6.8. Manual Outbound 16-Hour Counts

Table 18 gives the May 1999 and May 2000 weekday 16-hour (7:00 AM to 11:00 PM) flows by mode across the northern Downtown bridges for the outbound direction:

Table 18 May 1999 and May 2000 Weekday 16-Hour Outbound Flows by Mode

Bridge	May 1999 Vehicle	May 1999 Auto Occu-pants	May 1999 Transit Pass-engers	May 1999 Total Persons	May 2000 Vehicle	May 2000 Auto Occu-pants	May 2000 Transit Pass-engers	May 2000 Total Persons
Centre Street Upper	13032	16951	6390	23952	245	0	6507	6631
Centre Street Lower	5002	6542	0	6554	0	0	0	0
Louise Bridge	9427	11908	3311	15555	11507	14645	2846	17809
5th Ave Flyover / New Langevin	38676	46022	1748	50215	45954	56653	2283	62122
14th Street North accesses	4447	5533	470	6145	5223	6633	520	7316
Northeast LRT	87	0	14305	14305	88	0	15204	15204
Northwest LRT	97	0	10524	10524	99	0	11417	11417
TOTAL	70768	86956	36748	127250	63116	77931	38777	120499

Table 19 gives the differences in 16-hour (7:00 AM to 11:00 PM) flows between May 2000 and May 1999:

Table 19 Difference in May 2000 and May 1999 Weekday 16-Hour Outbound Flows by Mode

Bridge	2000 - 1999 Vehicles	2000 – 1999 Auto Occupants	2000 – 1999 Transit Passengers	2000 - 1999 Total Persons
Centre Street Upper	-12787	-16951	117	-17321
Centre Street Lower	-5002	-6542	0	-6554
Louise Bridge	2080	2737	-465	2254
5th Ave Flyover/New Langevin	7278	10631	535	11907
14th Street North accesses	776	1100	50	1171
Northeast LRT	1	0	899	899
Northwest LRT	2	0	893	893
Total Difference	-7652	-9025	2029	-6751
Total % Difference	-10.8%	-10.4%	5.5%	-5.3%

It can be seen for daily flows across the bridge screen-line:

- Total vehicle flow has decreased by 10.8%;
- Total auto occupant flow has decreased by 10.4%;
- Total transit passenger has increased by 5.5%;
- Total person flow has decreased by 5.3%.

i.e. total daily vehicle flow and total person flow across the bridge screen-line have both decreased overall, in spite of increases in vehicle and auto occupant flows on the alternative routes; and increases in transit flows on the Centre Street and other routes.

In contrast, daily weekday flows across the "control" southern Downtown screen-line (defined to encompass roads and transit routes between 14 Street W through 7 Street E) changed by the following percentages between May 1999 and May 2000:

- Total vehicle flow has decreased by 2.5%;
- Total auto occupant flow has decreased by 2.8%;
- Total transit passenger has increased by 4.2%;
- Total person flow has decreased by 1.1%.

On Bow Trail, vehicle and auto occupant flows increased slightly, by 0.3% and 1.8% respectively. Transit passenger flow was down 9.6%, leading to a total person flow decrease of 1.8%.

There was a more broad increase on 9th Avenue E, with increases of 22.0% and 16.2% for vehicle and auto occupant flows respectively, a transit passenger flow increase of 19.5% and a net overall total person flow increase of 14.8%.

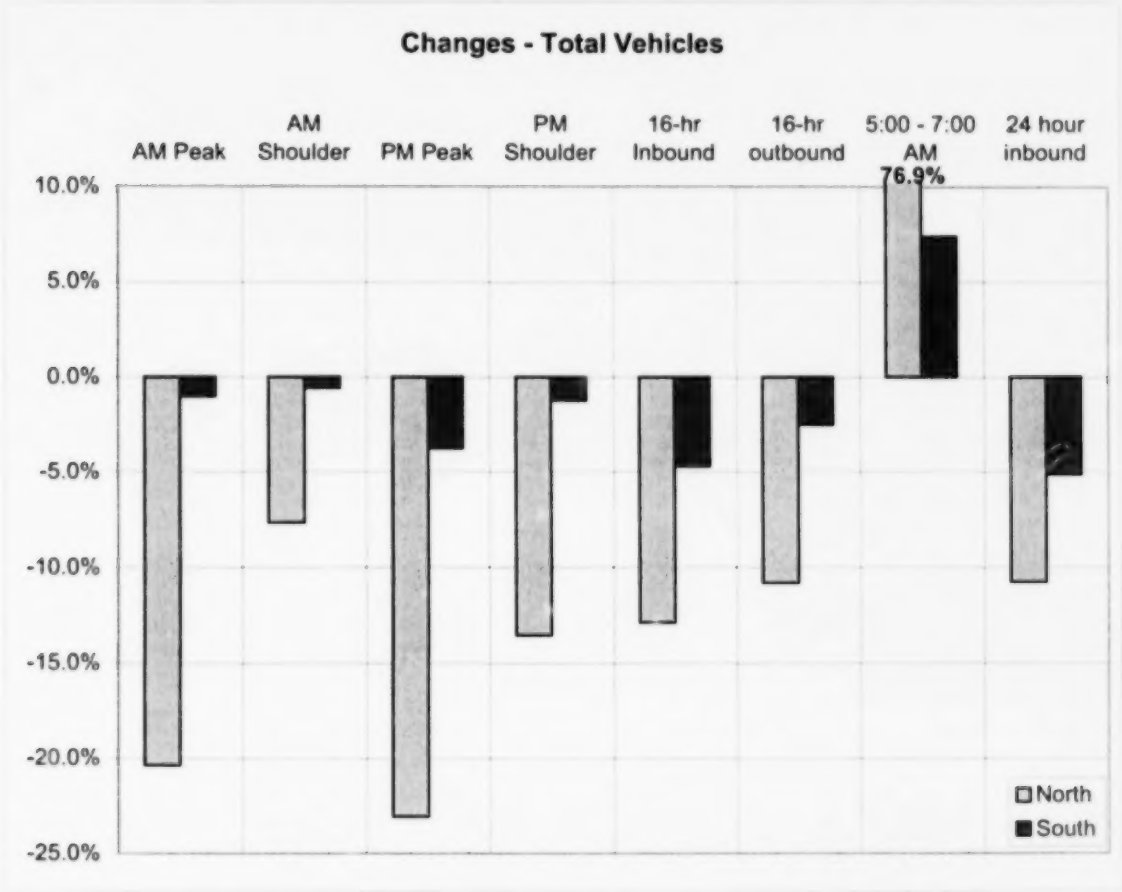
Considering passenger auto occupancy across the 16-hour measured period, including both directions, along north routes the total number of cars in the AM peak declined from 141821 to 124240 during the bridge closure. The total number of cars that crossed the screenline across the south routes in the AM peak also declined during the bridge closure, with 1999 volume of 123557 and 2000 volume of 118585.

These declines resulted in minor changes in occupancy. Along the north routes, average occupancy decreased from 1.280 people per vehicle in 1999 to 1.279 in 2000. Across south routes, occupancy also decreased from 1.250 to 1.244 people per vehicle. These trends represent a 0.1% decrease in the north and a 0.5% decrease in the south.

6.9. Summary of Changes in Observed Flows

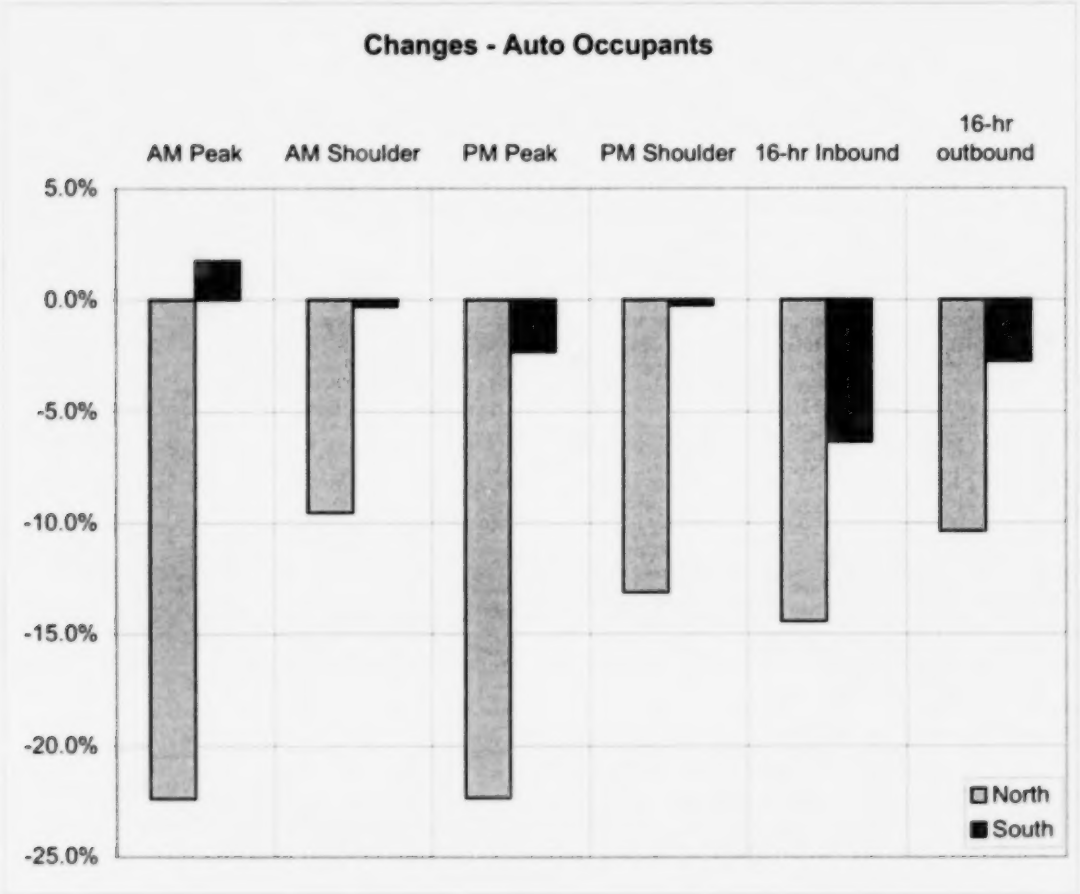
Total vehicle counts were lower in 2000 on both the north and south routes in all of the time periods observed, with the exception of the 5:00 AM to 7:00 AM period, which had very large gains (76.9%) in the north versus a modest gain (7.4%) in the south. In all other time periods, north total vehicles declined by more than south vehicles; for the six periods analysed using screenline data (AM peak and shoulder, PM peak and shoulder, 16-hour inbound and outbound), the average decline for north routes was 14.7%, compared with a 2.3% decline for south routes. This data is graphically summarised in Figure 4.

Fig. 4: 1999-2000 volume changes: total vehicle counts



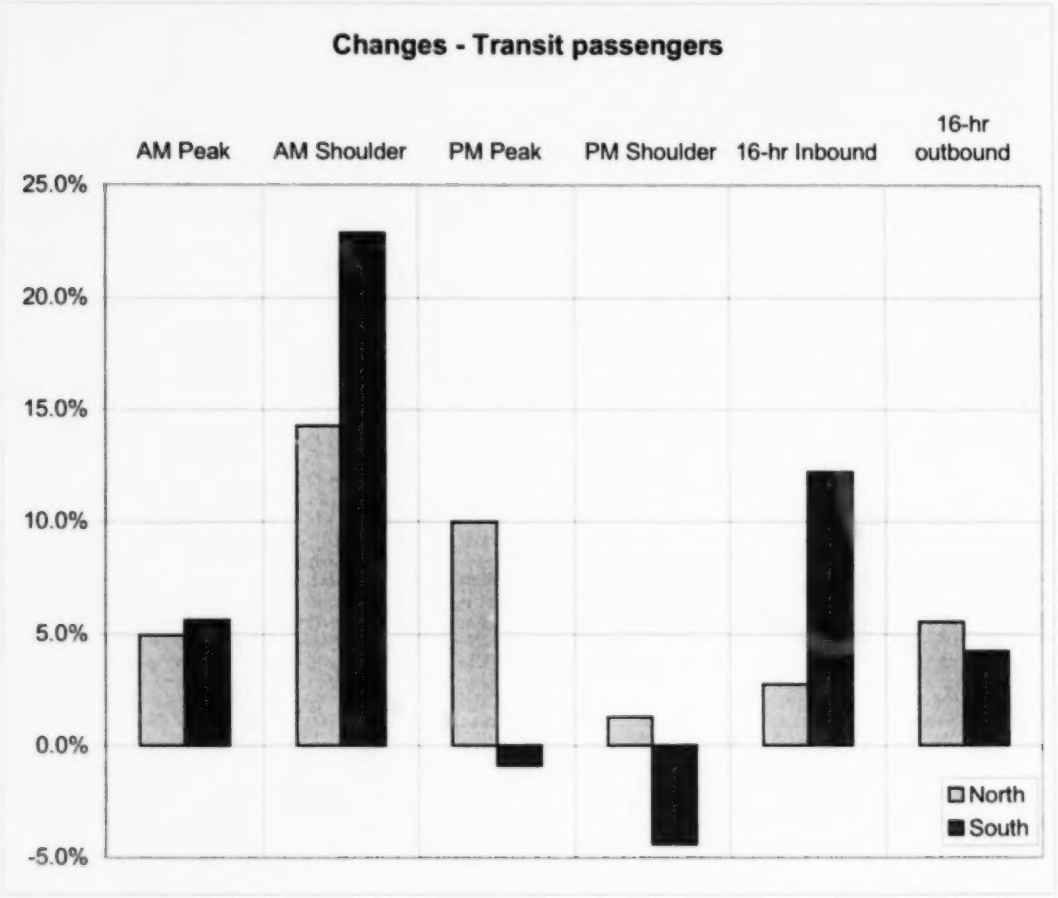
Auto occupant counts were also generally reduced during the bridge closure; only south routes in the AM peak hour showed a gain. North routes had a larger decline than the south routes during all six periods analysed with screenline data. The average decline for north routes in these time periods was 15.4% versus a 1.7% decline for south routes. This data is graphically summarised in Figure 5.

Fig. 5: 1999-2000 volume changes: auto occupant counts



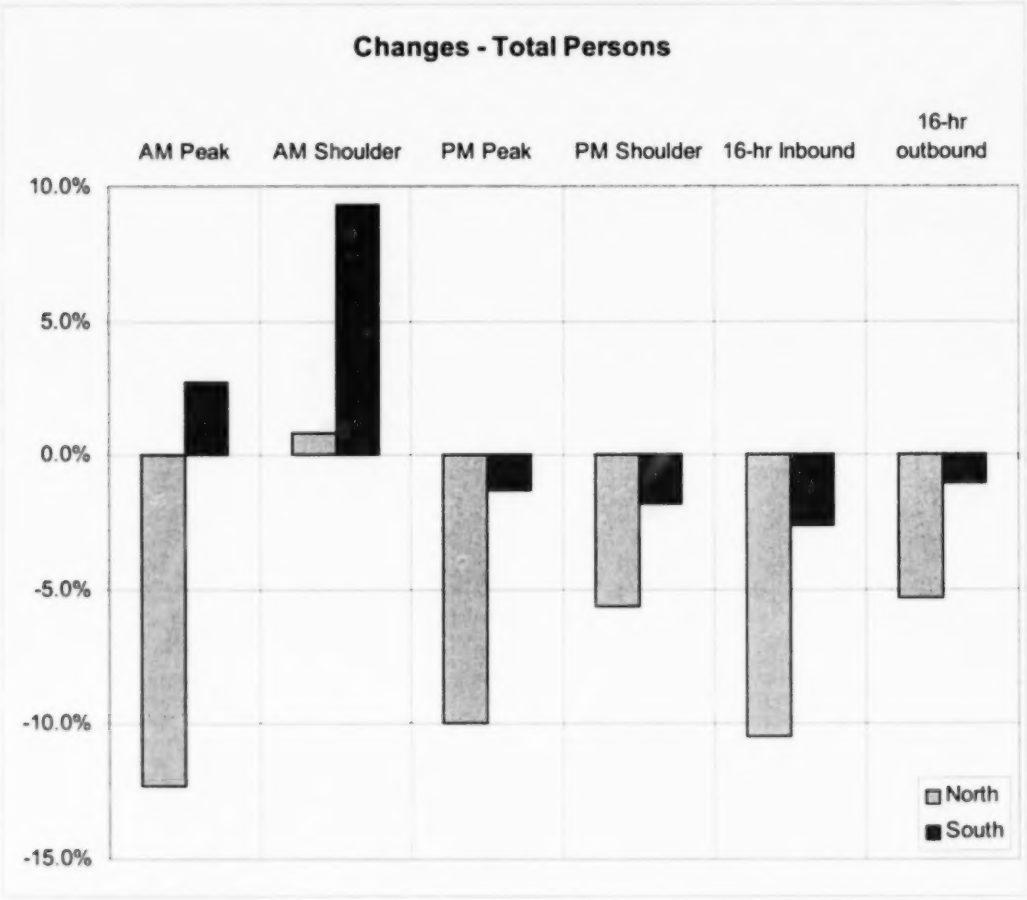
Transit passenger counts, however, were typically increased during the bridge closure; only south routes in the two hour PM peak period had a decline. There was less of a clear pattern with transit passengers; however, for the six periods analysed with screenline data, north routes had an average increase of 6.5%, compared with an increase of 6.6% for south routes. This data is graphically summarised in Figure 7.

Fig. 7: 1999-2000 volume changes: transit passenger counts



Overall person flows were typically reduced during the bridge closure. The only gains were showed in the AM shoulder, as well as along south routes in the AM peak hour. North routes had a larger decline or smaller gain than the south routes during all six periods analysed with screenline data. The average decline for north routes in these time periods was 7.1% versus a 0.9% gain for south routes. This data is graphically summarised in Figure 8.

Fig. 8: 1999-2000 volume changes: total person flows



6.10. Analysis of Changes in Observed Flows

With the bridge closure, there were four main potential classes of effects. Trips can shift routes, times, and/or modes, or they can be reduced. Reduction can also be considered to include trip chaining and destination shifting, which will appear to be trip reduction from the perspective of trips across a certain cordon.

6.10.1. Mode/Occupancy Shift

There are a variety of options for mode shifts; Calgary Transit was in full operation during the closure, and there are a number of pedestrian/cyclist

bridges into the downtown. These three modes, in fact, enjoyed the preferential status of continuing to use the Centre Street Bridge. Additionally, a shift from single occupant auto to the multiple occupant auto mode through carpooling could occur, and would result in a reduction of traffic.

The inbound transit passenger data for the 7:00 AM – 9:00 AM peak period is summarised in table 20 below:

Table 20 Inbound transit passenger flows and changes, 7:00 AM – 9:00 AM

Bridge	1999 Transit passengers	2000 Transit passengers	2000 – 1999 Transit passengers	2000 – 1999 Change (%)
Centre Street Upper	3300	3500	200	5.2%
Louise Bridge	1300	1200	-100	-9.1%
Langevin	800	700	-100	-14.8%
14th Street North accesses	150	150	-0	-6.8%
Northeast LRT	6050	6300	250	4.4%
Northwest LRT	4650	5950	1300	27.5%
Total North routes	16350	17800	1450	9.0%
East/West routes (Bow Trail / 9th Ave E)	4600	4500	-100	-2.0%
North plus East/West routes	20950	22350	1400	6.6%
South routes (incl. LRT)	9650	10850	1200	12.6%

It can be seen that there was an increase of 9% in transit passengers during this AM peak period on the northern routes. This may have been due to vehicle users switching to transit as a result of the Centre Street Bridge closure.

However, south transit routes showed an even bigger increase in ridership, of 13%, during the AM peak. It is therefore difficult to isolate the effects of the closure on transit ridership from the underlying changes that may have occurred due to demographic or other changes.

A similar tabular analysis can be performed for the metabolic (walking and cycling) modes studied. Because the pedestrian-only bridges (St. George's Island, Prince's Island and Northwest LRT pedestrian deck) were not counted in 1999, values were extrapolated for these facilities based on their 2000 volume and the 1999-2000 change on the other north pedestrian routes. These bridges constituted about half of the metabolic traffic flow in 2000. The metabolic mode data is summarised in table 21 below:

Table 21 Combined inbound metabolic flows and changes, 7:00 AM – 9:00 AM

Route	1999 Total	2000 Total	2000-1999	% Change
North (includes extrapolated data)	2760	2940	180	6.4%
East/West routes	650	690	40	6.0%
North plus East/West routes	3410	3620	220	6.3%
South Routes	3710	3640	-70	-1.9%

From this data, it can be seen that there was a similar increase in metabolic traffic flow on both the north and east/west routes, and that, in contrast, the south routes had a slight decrease. While this implies a switching from auto to metabolic modes on the north routes, the number of persons who switched is small in comparison to the total number using autos. The 220 person increase represents only 4% of the 5150 auto user reduction reported in table 1. The conclusion, therefore, is that there was a clear increase in metabolic transportation mode choice, but that this is a small part of the overall picture.

A third possible mode change was from single occupant vehicles to high occupancy vehicles; this would result in an increased occupancy rate. The occupancy rates before and during the closure are summarised in table 22 below:

Table 22 Inbound auto occupancy, 7:00 AM – 9:00 AM

Route	1999 Occupancy	2000 Occupancy	% Change
North	1.267	1.241	-2.0%
East/West routes	1.230	1.228	-0.2%
North plus East/West routes	1.255	1.237	-1.5%
South Routes	1.206	1.229	1.9%

The north routes exhibited a small decline in occupancy, in contrast to a similarly small increase in south route occupancy and very little change in occupancy on the east/west routes. The decline on the north may have been due to the bridge closure (the two decks of the Centre Street Bridge were the two routes with the highest occupancy prior to the closure). Although the changes are fairly small, it appears that whatever effect the closure had on vehicle occupancy appears to have been a negative one, which would increase pressure on other modes of travel, or reduce any trip reduction phenomenon.

6.10.2. Route shifts

The obvious route shift in the Centre Street Bridge closure was from the Centre Street Bridge to other routes, but there may have been secondary shifts between parallel routes as some routes were more heavily used. The general shifts were from Centre Street to parallel routes, and from congested parallel

routes to less congested parallel routes. The route shifts are shown below in table 23.

Table 23 Vehicle flow changes, peaks and 24-hour

Route	Change, AM Peak 2 hrs	Change, PM Peak 2 hrs	Change, 24 Hour
Centre Street Upper (A)	-3429	-3658	-12522
Centre Street Lower (B) (synthetic data)	-1553	-1633	-4009
5th Ave Flyover/New Langevin	N/A	915	N/A
4th Ave Flyover	93	N/A	261
Langevin	1272	N/A	4883
Louise Bridge (synthetic data)	438	763	1806
14th Street North accesses	288	229	1015
9 Ave E	402	714	1361
Bow Trail	98	-58	2070
Total net change (C)	-2391	-2798	-5134
Percent of Centre Street traffic explained as route shift = 1-(C/(A+B))	52.0%	48.4%	68.9%

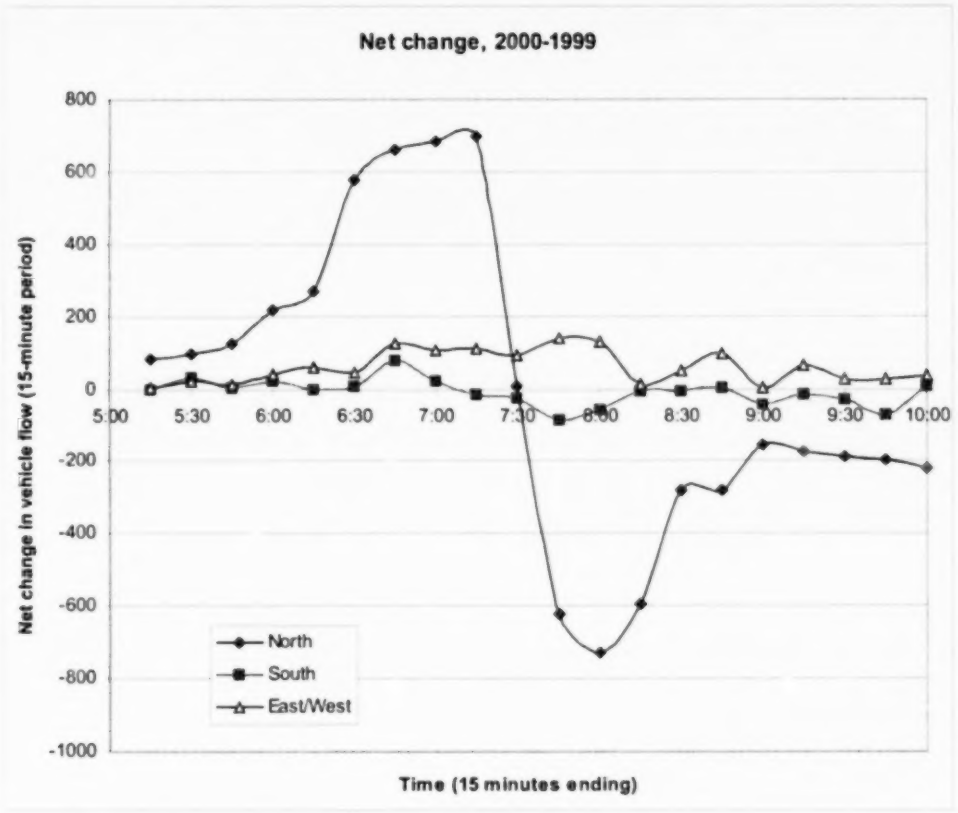
NB: AM and PM peak in peak direction only.

It is instructive to see that about half of the traffic on the Centre Street Bridge shifted to become a surplus on other routes during the peaks, and that about two thirds of the total traffic on the Centre Street Bridge shifted to become a surplus on other routes during the total 24-hour day. In other words, a majority of travellers shifted routes, rather than shifting modes or reducing trips. The reason that a greater percent of Centre Street Bridge traffic was accompanied by observed gains on parallel routes during the 24-hour count as opposed to the peak period counts is due to time shifting.

6.10.3. Time Shift

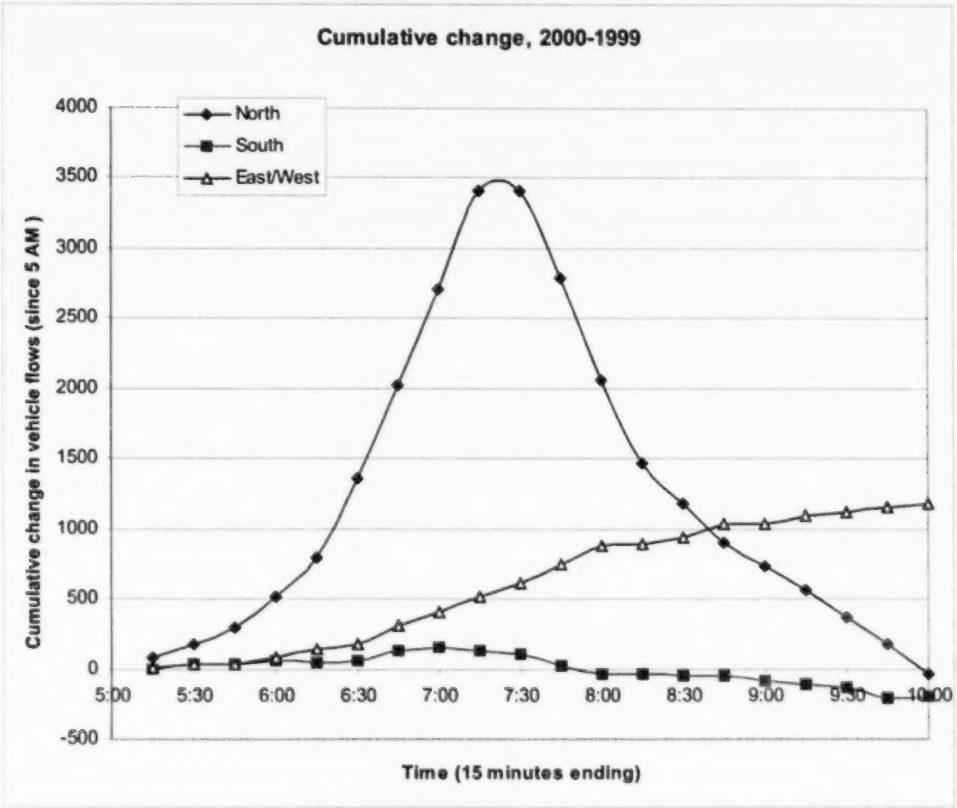
Figure 2 below shows the net change in vehicles between 1999 and 2000 (i.e. 2000 vehicle flow – 1999 vehicle flow) for the north, east/west and south routes. The south route is shown to have very similar traffic flows, resulting in a net change of nearly zero for all time periods. In contrast, the east/west routes have small net changes, but they are all positive; in other words, there was a small, but noticeable increase in traffic. This increase was greatest during the traditional 7 AM – 9 AM peak hours. The real difference, however, was in the north, where the net change in traffic steadily increased to a large difference of almost 700 extra vehicles in the 7:00-7:15 AM period; then, over the next half an hour, switched to a reduction of over 700 vehicles for the 7:45-8:00 AM period.

Fig. 9: Net change, 1999-2000, in AM vehicle flows per 15 minutes



If these net values are converted into a cumulative change, starting at 5:00 AM, as shown in figure 3 below, then a time shift is apparent. During this five-hour period, the cumulative change on the south control routes are minimal, with a slight increase during the AM peak, but a small cumulative reduction by 10:00 AM. On the east/west routes, the small changes visible on the previous graph accumulate, leading to a fairly steady cumulative increase to a gain of over 1000 vehicles by 10:00 AM. The north routes, on the other hand, show a cumulative increase of almost 3500 vehicles by 7:15 AM, which then decreases to a very small cumulative reduction by 10:00 AM.

Fig. 10: Cumulative change, 1999-2000, from 5:00 to 10:00 AM



Thirdly, if the time that the median vehicle from the 5:00 – 10:00 AM period crosses the cordons is determined, another argument is made for a time shift towards earlier trips. The median vehicle crossed the south cordon at 8:01 AM in 1999 and at 8:00 AM in 2000, one minute earlier. The median vehicle crossed the east/west cordon at 7:54 AM in 1999 and at 7:50 AM in 2000, four minutes earlier. However, the median vehicle crossed the north cordon at 8:01 AM in 1999 and at 7:46 AM in 2000, a full fifteen minutes earlier.

The conclusion that can be drawn from this data is that a large percentage of the vehicles that normally would have travelled on the Centre Street Bridge combined with existing traffic flows on the north routes, as well as on the east/west routes to some degree. Due to this additional traffic, users of these routes were forced to shift the time of their trips, travelling earlier and in a more spread-out fashion, as the road system was at or very near capacity during the normal peak.

6.10.4. Trip Reduction

To compare this data with the Goodwin study, the same calculations can be performed. A reduction of 10.2% in daily traffic in the area results if 24-hour traffic flows from the north alone are considered, with the synthetic Louise Bridge data is included. The reduction is 4.4% if the synthetic Louise Bridge is included, along with the east and west routes. The results of the Calgary calculations with this last assumption are included in table 17, which is based on table 4 presented earlier in this report.

Table 24 Observed Changes in Traffic Flow for Bridge Closures / Major Capacity Reductions

Bridge	Date & Length Closure	Daily Traffic Flow	Change in Daily Traffic in Area	% Change in Daily Traffic in Area
Hobart, Australia	1975, 14 months	44,000	-27,000	-61%
Tower Bridge, London	1993, 1 month	44,000	-35,000	-24%
Kinnaird Bridge, Edmonton	1979, 3 weeks	1,300 peak hour	-550 peak hour	-16%
Hammersmith Bridge, London	1997, 1 month	31,000	-10,000	-8%
Calgary, Centre Street Bridge	1999-2000, 14 months	34,000	-5,134	-4.4%
York, England	1978/9, 1 month	16,000	-3,000	-4%
Munich, Germany	1988	32,000	0	0%
Frankfurt, Germany	1989	29,500	500	+0.3%

The actual reduction in traffic flows, then, can be considered to likely have fallen between the 10.2% reduction considering north routes alone and the 4.4% reduction shown above including north routes as well as east and west routes. Examining the 'control' of the three major south routes in the same manner, however, shows a 5.1% overall reduction (down 2720 vehicles on 1999 24-hour flows of 53,163). It appears, then, that the net reduction in traffic due to the Centre Street Bridge closure is, at most, 5% to 6%.

7. Analysis of Survey Data: Aggregate Level

7.1. Aggregate Analysis Methodology

The aggregate analysis of survey data was based on the survey done by International Results Group. This survey, the methodology of the survey, and the major findings in the International Results Group report were described in detail in section 4.

Additional analysis of the survey data was done by HBA Specto, as a preparation for the disaggregate analysis, to compare with the observed data analysis, and for its own merit.

7.2. Aggregate Changes In Flows

7.2.1. Mode Choice and Mode Change

The survey data was limited with regards to an examination of mode change; it only included auto users, and thus could only report on a limited range of potential changes; persons who were travelling by metabolic (walk/bike) or transit modes were not included, so changes to auto from other modes were not available.

The first notable comparison is between the modes used before the bridge closure by Centre Street Bridge users and other bridge users. Centre Street Bridge users were more likely to use high occupancy vehicles, either as a driver or a passenger, and correspondingly less likely to be a single driver. An occupancy figure can be calculated as well, using the stated typical number of passengers for HOV drivers. This data, both occupancy and mode choice is summarized in table 25.

Table 25 Mode Choice Before Closure: Centre Street Bridge users vs. others

Bridge	Percent SOV Drivers	Percent HOV Driver	Percent HOV Passenger	Occupancy
Centre Street Bridge	54.4%	28.6%	17.0%	1.42
Others	59.4%	26.2%	14.4%	1.36

After the closure, the following mode changes were reported in the survey:

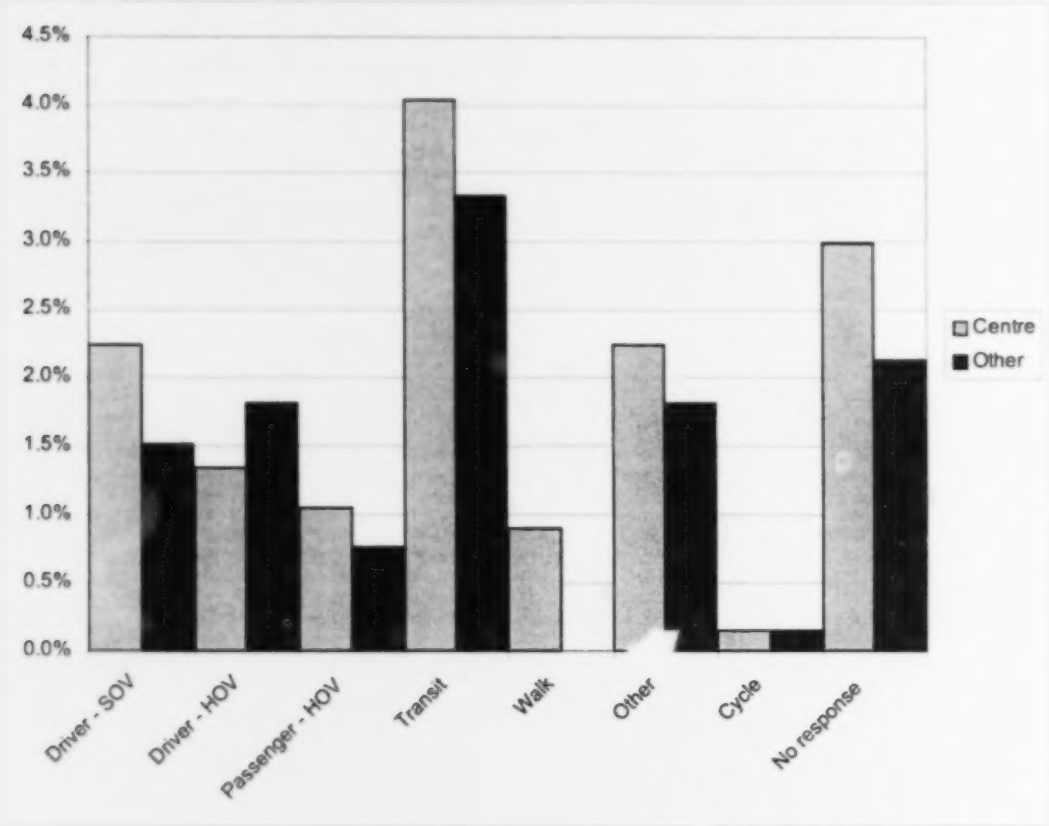
Table 26 Mode Choice During Closure: Centre Street Bridge users vs. others

Bridge	No Change	To Other Auto-Based	To Transit	To Metabolic	Other / No Change
Centre Street Bridge	85.1%	4.6%	4.0%	1.0%	5.2%
Others	88.5%	4.1%	3.3%	0.1%	3.9%

There are several notable results here. Firstly, mode changes were less significant than might have been anticipated; only 10.7% of all surveyed people reported changing mode at all. Furthermore, 26.1% of these respondents who switched remained drivers an d merely changed the number of passengers in their vehicle (switched from HOV to SOV or vice-versa). It is also instructive to observe that Centre Street users were more likely to change to another mode, but not overwhelmingly; they changed modes at a rate of 12.0% versus the 9.4% of non-Centre Street users.

As to the specific modes chosen by users who changed, the two groups displayed fairly similar characteristics, as shown in the graph below. About one third of these users who changed mode shifted to another auto-based mode, 28% changed to transit, 19% failed to respond, 15% selected 'other', and the remaining few percent selected metabolic-based modes of walking and cycling.

Fig. 11: Percent of all users who switched to another mode, by mode and bridge



The two main differences between the Centre Street Bridge users and those who used other routes were in the propensity of the former to walk and the latter to carpool. A total of 6.0% of the Centre Street Bridge users surveyed who switched modes switched to walking during the closure, where none of the non-Centre Street Bridge users did. On the other hand, 15.8% of the other route users reported becoming drivers of HOVs, where only 9.0% of the Centre Street Bridge users did. This finding may be suspect, considering that Centre Street Bridge and other route users switched to becoming passengers of HOVs at almost the same rate (7.0% and 6.6%, respectively).

For the 27 respondents who switched to 'other' modes, the frequency of the various responses was as follows:

Table 27 Switches to "Other" modes

"Other" Mode	Number of responses
Car one way then transit return	10
Skip	9
Car part way then bus	4
Drive and walk	2
Pedestrian (unspecified)	1
Drive and cycle	1

The majority (51.9%) were 'park and ride' type car-transit combined trips; another 33.3% were actually skip codes.

7.2.2. Trip Reduction

Of the 1352 respondents, 36 (2.66%) indicated that they no longer made the same trip that they had when the bridge was open. These respondents were asked a supplementary open-ended question as to their reason for no longer making the trip.

These responses can be considered to fall into three basic types; 'life changes', those where external factors affected the need to make the trip in question, 'transportation changes', those where external or internal factors caused the respondent to change the way in which they make the trip (but in which the trip was still made), and 'trip reductions', those changes where the trip was not made due to internal factors. A large portion of the responses fell into a fourth category 'unknown', which represents responses that provided insufficient information to divide them into the other three categories. (This included statements such as "I no longer go downtown", without any information as to why.)

The summary of trip reduction reasons is noted in the chart below:

Table 28 Summary of Reasons for Trip Reduction

Reason	Type	Responses	Percent of reduced trips
Changed jobs/office location	External	13	36.1%
No longer go downtown	Unknown	11	30.6%
On maternity leave	External	4	11.1%
Changed residences	External	2	5.6%
Unemployed now	External	1	2.8%
Carpool opportunity no longer avail.	Transportation	1	2.8%
No longer drop off passenger	Transportation	1	2.8%
Purchased vehicle so now drives	Transportation	1	2.8%
Bridge closed and it's now inconvenient	Reduction	1	2.8%
Trip takes too long	Reduction	1	2.8%
Total		36	100%

This illustrates that the reported reduction in trips from the survey is very low; only 5.6% of responses represented reductions that could be attributed to

changed transportation supply conditions, rather than an external condition such as the onset of a maternity leave. Considering that this is only 2.7% of the total survey data, the total reduction in trip flow could be as small as 0.15% of the total trip population.

If the unknown results are all included as trip reductions, this accounts for 36.1% of the reduced trips, which represents 0.96% of the total population, still a small number.

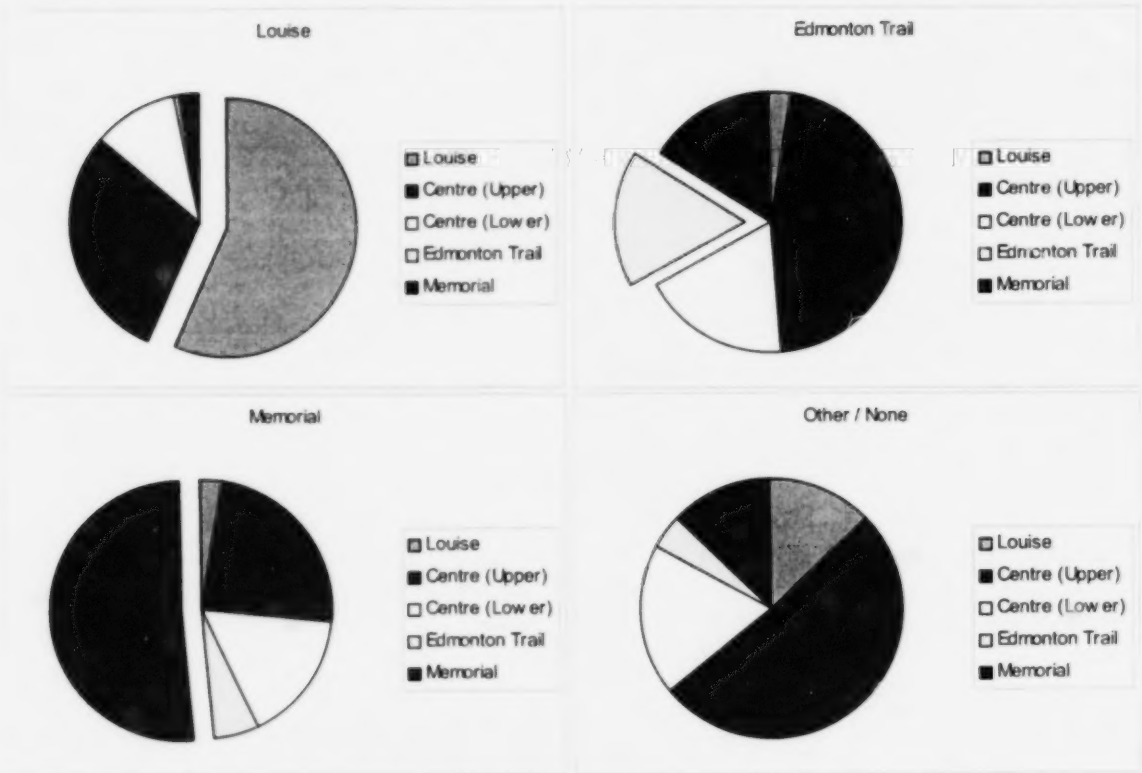
7.3. Route Change

Using the primary trip before and during the closure, some interesting results can be seen with respect to the route changes of drivers as surveyed.

Centre Street users shifted in generally similar patterns, with users of both decks switching about 30% to the Edmonton Trail complex, 25% to the Louise bridge, and just under 20% to other routes. The main differences were in the switches to the Memorial Drive Flyover, which was chosen by 22% of lower deck users, but only 14% of upper deck users, and the switch to 14th Street, which was chosen by 10% of upper deck users, but only 4% of lower deck users.

An interesting note is the 'cross-over' switching between users of the Edmonton Trail complex and the nearby Memorial Drive flyover; 5.2% of the Memorial Drive users switched to Edmonton Trail, with a full 16.7% of Edmonton Trail users switching back to Memorial Drive. The total reported trips made daily by surveyed users are reported in figure 12.

Fig. 12: Trips reported for bridges during closure, based on pre-closure trips



7.4. Aggregate Analysis Compared to Observed Data

7.4.1. Mode Change

The structure of the survey was such that it is not always directly comparable to observed data with regards to mode. There are several reasons for this. Firstly, the survey only included auto users, and thus would be expected to show more auto users during the closure than in observed data. Secondly, the survey was done in November/December, while the observed data counts were done in May, which, due to weather effects, could reasonably be assumed to result in greater numbers of people using metabolic modes (walking/cycling) as well as transit (since transit trips usually involve walking segments, as well as potential waiting outside).

In comparing the 'Before' survey with the observed 1999 count, the occupancy is the most representative value. Both Centre Street Bridge and other routes indicated a higher occupancy in the survey data than in the actual counts (this seems reasonable, considering human nature), but the higher occupancy was on Centre Street Bridge for both the 7-9 AM count data and the calculated occupancy based on survey results. These results are summarised in table xx. It can be seen that occupancies are similar, and that in both cases that the Centre Street Bridge has higher occupancy, by about the same relative amount.

Table 29 Occupancy (Centre Street Bridge users vs. others) – Observed vs. Aggregate

Bridge	Occupancy (observed, 7-9 AM inbound count)	Occupancy (calculated from survey)
Centre Street Bridge	1.30	1.42
Others	1.25	1.36

7.4.2. Trip Reductions

Depending on the level of consideration given to the east and west routes as alternates for traffic from Centre Street Bridge and its' alternates, the 'real world' traffic reduction was shown to be in the range of 0-6%.

In the aggregate data, less than 1% of users reported a 'reduction' type reason for no longer travelling downtown. It is reasonable to assume that 'external' and 'transportation' types of reasons for not making trips would generally result in a negligible change in traffic. For instance, one 'external' reason was "On maternity leave"; presumably the rates of people going on and returning from maternity leave will balance out.

The discrepancy between 0-6% reduction from the observed data and the < 1% reduction rate in the aggregate data is not a large one. A possible explanation is the survey methodology; the survey concentrated on peak-period users, typically home-to-work commuters. It's possible that a proportionally greater portion of reduced trips came from other sectors, such as shopping or leisure trips.

7.4.3. Route Change

The sample used in the survey deliberately overweighted Centre Street Bridge users. However, if a weighting system is used, it is possible to determine what traffic levels would have been predicted by the aggregate data. The two-hour AM peak period was examined, as it was thought to be most representative of the aggregate surveys.

A weight for survey responses for each bridge was developed based on the AM peak period. As an example, each of the 337 respondents who used the Louise bridge before closure was considered to represent 13.1 AM peak period vehicles (there were 4408 peak period vehicles in 1999 on the Louise Bridge; 4408/337 = 13.1). When 5 survey respondents who used the Louise Bridge before closure switched to the Memorial Drive/4th Ave Flyover, an increase in traffic on that bridge of 65 (=13.1*5) vehicles was predicted.

Using this technique for the AM peak period, 2000 traffic on the Louise Bridge was predicted to be 5217 vehicles, 7.1% higher than actual flows of 4846 vehicles. Similarly, on the Langevin Bridge, predicted flows were 4167, 7.4% lower than actual flows of 4474 vehicles, and on the 4th Ave Flyover, the prediction was for 5215 vehicles, 4.5% higher than the actual value of 4981.

These results seem to indicate that the survey was reasonably accurate in predicting route changes; however, the survey was limited in that it did not include 14th Street or any potential east-west accesses, such as Crowchild Trail to Bow Trail.

8. Analysis of Survey Data: Disaggregate Level

8.1. Basic Methodology of Disaggregate Analysis

The goal of the disaggregate analysis is to develop a model that is applicable to a broad range of situations by examining the root factors that affect a decision. Both properties of the choices (the cost of different options, the time taken, the nature, and so on), and properties of the individuals making the choice (income, gender, age, and so on) can be examined. A mathematical model that reflects the influence that these properties have on a decision is then created.

The software used for this analysis was the Hague Consulting Group's ALOGIT package, version 3.2f. Data preparation, done to convert the survey data to include all of the possibly useful choice and personal data was done in the SAS system.

The data set was highly limited in its' application to disaggregate analysis, however. One main problem with the data set was the overall size limitation; it is difficult to model with only 1352 surveys, due to various problems with the data. Major causes of data problems were related to the parking values.

About one third of the data had insufficient parking information, missing a cost or distance. (If only one cost was available, either before or during the closure, then it was assumed to apply for both before and during trips. This was necessary for various reasons; for instance, if a survey respondent took transit during the closure, they would not have a parking cost.)

Of the data with complete parking information, an additional third had 'parking perks', which were defined as parking for free at the same location as work. This skewed the attractiveness of parking and walking; normally, parking that is convenient to the workplace is more likely to be more expensive. The existence of so many results with free parking at work skewed the data, so that on average, parking was less expensive the closer it was to work. This data was removed.

Of this remaining data, about 12% were not home-to-work trips, or were not made in the AM Peak. People making trips other than home-to-work can handle them differently; for instance, if traffic increases, a home-to-shopping

trip can be made to a more local store. A trip from home to work has typically fixed origin and destination, and a limit on the time it can be made. AM Peak trips can only reasonably be compared with other AM peak trips; transit availability, traffic levels and a variety of other important parameters are different outside the peak. Furthermore, the EMME/2 model the City of Calgary currently uses is an AM Peak only model; data from this model was used to determine the length of the various trips to create the set of alternates.

Once records that were not suitable for the above reasons were removed, and the records that ALOGIT could not use were removed, a total of 361 observations were available for use in the model.

8.2. Results of Disaggregate Analysis

A wide variety of disaggregate model forms were tried; the one with the best predictive value was a single level three-option mode choice model with auto, transit and walking as the three modes. AM Peak home-to-work trips were considered; this included only 361 complete observations.

The model has the following form:

	t-ratio
U(auto) =	
-0.09358 * (cost of parking + cost of vehicle operation [$])	-1.1
-0.1001 * in-vehicle trip time [min]	-0.7
-0.000652 * Manhattan walking distance, parking-work [m]	-1.0
+1.309 * (1 if a return trip is made)	+3.1
-0.1403 * (1 if flexible hours are offered at work)	-0.3
U(transit) =	
-0.09358 * cost of transit fare [$]	-1.1
-0.1001 * in-transit ride time [min]	-0.7
-0.07067 * (walk to transit + transfer + wait time [min])	-0.6
-0.2279 * (1 if person is female)	-0.5

-0.6876 * (1 if person is over 45 years old)	-1.2
-0.4765 * (1 if person is employed full-time)	-0.8
-1.907	-1.8

U(walk) =

-0.000652 * walking distance from home to work [m]	-1.0
-0.6876 * (1 if person is over 45 years old)	-1.2
-0.4765 * (1 if person is employed full-time)	-0.8
-3.260	-4.1

This model is not ideal; the t-ratios, a general measure of the significance of the coefficients developed, are very low.

Another way to consider a model is by analysing the implied value of time. By dividing a coefficient associated with a time variable by the coefficient for cost, a value of time in units of $/min (convertible into $/h) is produced. This works out to be higher than traditional disaggregate models develop; it is $64.18/hr for transit or car ride time and $45.31/hr for transit walking/waiting/transfer time. If a walking speed of 5 km/h is assumed, the time value for walking is $34.84/hr. This time value is typically closer to the $12/hr range, in line with typical wages.

The probable reasons for this discrepancy are due to the limitations of the survey data. Firstly, only selecting auto users will likely bias the study to a more affluent population, who would presumably have higher wages and a higher value of time. More significantly, the population initially surveyed are initially auto users only. They would likely be reluctant to switch modes; indeed, of the 361 observations, only 25 (4.3%) switched to non-auto modes. This internal inertia and reluctance to switch modes would be interpreted by the modelling software instead as a strong preference for the more costly (but faster) auto modes over the slower, cheaper transit and walking modes.

As a sample calculation to demonstrate this deficiency, assume a male under 45 who works full-time with no flex available and makes a return trip. Furthermore, transit is assumed to involve 15 minutes of transfers, walking and waiting, and a 25 minute ride, while auto is assumed to offer a 20 minute ride and a 250 m walk from parking. To make all three modes equally

attractive, the walking distance would have to be 5700m, and the cost associated with auto would have to be $35.66.

An additional limitation in the data with a less obvious effect is the reliance on 'typical behaviour' as opposed to a specific day. People have a general tendency to smooth over the unusual when asked this question, and state what they believe they typically do. While trips that are typically made are the majority of the traffic flow, unusual trips to constitute a significant portion; if a person's activities on a specific day are asked for, then these trips are also captured.

9. Conclusions and Implications for Future Roadway Capacity Reduction Projects

9.1. Major responses to Centre Street Bridge closure

In general, the responses people make to roadway capacity reductions will be determined by:

- The level of capacity reduction with respect to existing traffic flow
- The level of flow affected directly
- The amount of provision of extra roadway capacity in the immediate corridor
- The relative attractiveness of alternative routes and their spare capacity
- The type of trip affected
- The availability and attractiveness of alternative modes
- The relative attractiveness of alternative locations
- The amount of information provided about the reduction / availability of alternatives

The four major potential response areas to the Centre Street Bridge closure were in the changing of route, time and mode, as well as trip reduction. Of these four potential responses, it was seen that the most common responses were the change of routes and time, with mode and reduction changes having little effect.

Route changes included the obvious switch away from the Centre Street Bridge, as it was impassable. However, the survey noted a shift between parallel open routes; for instance, about 10% of the combined users of the Langevin Bridge and 4th Street Flyover had switched to the other route during the closure.

The general result of these shifts, both 'primary' from the unavailable Centre Street Bridge and 'secondary' from one open route to another, was an increase towards capacity on unfilled routes. As an example, over the 24-hour period,

the busy 4th Ave Flyover increased in volume by less than 1%, where the less-used Langevin Bridge had flows increase by 30%.

Time changes were the other major response to the Centre Street Bridge closure; vehicles travelled earlier and over a more widely spread peak, since the reduced capacity meant that the system operated at or near capacity for a longer period of time.

While a reduction in AM inbound peak hour volume of over 20% was noted on the north routes, for instance, with a smaller decrease of about 7% in the AM peak shoulder period, the 'preshoulder', or two-hour period preceding the peak, had an increase in volume of 65%. It was also observed that there was a net increase of almost 3500 vehicles crossing the screenline during the two and a half hours from 5:00 – 7:30, followed by a net decrease of almost the same number of vehicles during the two and a half hours from 7:30 to 10:00. These results are very strong arguments for a peak shift.

The main response could therefore be said to be the shifting of Centre Street Bridge vehicles onto alternate routes, with all traffic employing a strategy of both shifting to alternate routes and making the trip earlier.

Mode changes were considered to have minimal effect during the closure; for instance, north routes had a transit increase of 9%, but south routes had a transit increase of over 12% observed. While there was a larger shift to metabolic transportation modes in the north than in the south control routes, this difference was small in comparison to the total amount of traffic.

Similarly, the overall rate of trip reduction was determined to be less than 5% of the total trips made; while there was a reduction of over 10% on the north routes alone, if these were combined with east/west routes, the reduction declined to only 4.4%, less than the reduction along the south routes.

The Calgary reduction of 5% or less was comparable to a number of cases that were studied by Goodwin, but was significantly less than the extreme values reported by that survey.

9.2. Major Implications

This study has implications in three major areas; planning, modelling and data collection.

It was seen that the major responses to a reduction in the transportation supply were in the changing of routes and of the time of travel. Planning for future reductions in transportation should therefore emphasize alternate route availability, while also considering the potential effects of peak spreading.

While this study was done of a reduction in the transportation supply, it is reasonable to consider these factors for the situation of increase in transportation demand outstripping transportation supply. As roads become more congested, the peak will spread and drivers will seek less crowded alternates, and this is important in both the planning and operation of transportation systems.

The main implication for modelling is the importance of time shifting. The current models used by the city provide for the potential to shift modes and to shift routes, but the importance of a peak shift is not considered. Without this peak shift accounted for, models will tend to overstate the importance of mode shifts, and will predict greater use for transit and metabolic modes than would happen. Again, this is important not just in the situation of a decrease in the transportation supply due to road closure, but also to the more general case of transportation demand increasing more rapidly than transportation supply.

One of the main frustrations in the observed data analysis was the late start of traffic counts. Transit shifts could not be entirely considered; it is impossible to say whether transit users also performed a peak shift due to the closure, as data is unavailable from before 7:00 AM. In 2000, about 30% of the total vehicle flow during the 5:00 AM – 9:00 AM period occurred in the 5:00 – 7:00 AM period where manual counts were not being done. With this large portion of traffic, and the importance of the peak shift, greater data collection in this period would be very helpful. As congestion increases, if the peak shifting seen with the Centre Street Bridge closure continues, a larger proportion of traffic will shift to before this data collection begins.

9.3. Study design and execution

The Centre Street Bridge study had both positive and negative factors associated with it. It is important to learn from the negative factors for future studies, while maintaining the positive factors.

The survey was limiting; the auto-only focus restricted the value of mode choice data, and the lack of fully complete results for all questions made modelling difficult. Furthermore, the emphasis on 'typical behaviour' rather than a specific day's actions would result in data that is actually less representative of what typically happens in the City of Calgary on a given day. The overall limits of this survey hampered efforts to develop a useful disaggregate model. Additionally, the limited count data from before 7 AM reduced the ability to analyse the peak shifting phenomenon, which was the most significant result of the study.

On the other hand, the time shifting phenomenon was clearly observed, which is a very useful result. Additionally, the survey and count data generally

reflected each other, and the count data gave comparable results to other cities. The overall goal, of categorizing and analyzing the transportation responses to the closure of the Centre Street Bridge was clearly met, and these answers have strong implications and value.

10. References

Goodwin P., Hass-Klau C., and Cairns S., Evidence on the Effects of Road Capacity Reductions on Traffic Levels. Traffic Engineering and Control, June 1998, Ps. 348-354.

11. Appendix B

IRG submitted a report "A Survey and Study on the Centre Street Bridge Closure", which summarized the survey method and results, in 2000. Tables B.1 to B.3 summarize the figures, tables and tabulations contained in the IRG report:

Table B.1 Figures in IRG Report

Title	Description	Before/ During Closure	Respondents
Figure 1	Bridge Used	Before /During	All
Figure 2	Change in Route	During	Centre Street Users
Figure 3	Change in Travel Mode	During	All who changed mode
Figure 4	Travel Time	Before	All
Figure 5	Travel Time	During	All who continued to travel
Figure 6	Travel Time Before/During	Before /During	All who continued to travel
Figure 7	Change in Travel Time	During	All who continued to travel
Figure 8	Travel Time Before, by Route	Before	All
Figure 9	Travel Time During, by Route	During	All who continued to travel
Figure 10	Change in Departure Time	During	All who continued to travel
Figure 11	Change in Arrival Time (First Stop)	During	All who continued to travel
Figure 12	Change in Arrival Time (Final Stop)	During	All who continued to travel
Figure 13	Return Travel Time	Before	All who made return trip
Figure 14	Differences in Trip / Return Trip Travel Time	Before	All who made return trip
Figure 15	Return Travel Time	During	All who made return trip
Figure 16	Return Travel Time Before/During	Before /During	All who made return trips before / during
Figure 17	Change in Return Travel Time	During	All who made return trips before / during
Figure 18	Change in Trip / Return Trip Travel Time	During	All who made return trips before / during
Figure 19	Consideration for Using Transit	During	All who continued to travel not by transit

Table B.2 Tables in IRG Report

Title	Description	Before /During Closure	Respondents
Table 1	Data Collection Statistics	Before	All
Table 2	Trip Purpose First and Final Stop	Before	All
Table 3	Trips Made / Not Made by Purpose	During	All
Table 4	Change in Parking Location / Cost	During	All who continued to travel by car
Table 5	Demographics of Transit Users	During	All who switched to transit
Table 6	Demographics by Awareness Closure	Before /During	All
Table 7	Sources of Information on Closure	Before /During	All
Table 8	Demographics of Those with Flexible Hours	During	All with flexible hours

Table B.3 Tabulations in IRG Report

Title	Description	Before /During Closure	Respondents
Table 1	Travel Route Before by Travel Route During	Before /During	All
Table 2	Travel Mode Before by Travel Mode During	Before /During	All
Table 2A	Change in Travel Mode by Gender	During	All
Table 2B	Change in Travel Mode by Age	During	All
Table 2C	Change in Travel Mode by Employment Status	During	All
Table 3	Trip Purpose First / Final Stop	Before	All
Table 4	Trip Made During by Purpose Before	Before /During	All who continued to travel
Table 5	Travel Time Before	Before	All
Table 6	Travel Time During	During	All who continued to travel
Table 7	Change in Travel Time	Before /During	All who continued to travel
Table 8	Travel Time Before, by Route	Before	All
Table 9	Travel Time During, by Route	During	All who continued to travel
Table 10	Change in Departure Time	During	All who continued to travel

Table B.2 Tables in IRG Report

	Description	Before /During Closure	Respondents
Table 1	Data Collection Statistics	Before	All
Table 2	Trip Purpose First and Final Stop	Before	All
Table 3	Trips Made / Not Made by Purpose	During	All
Table 4	Change in Parking Location / Cost	During	All who continued to travel by car
Table 5	Demographics of Transit Users	During	All who switched to transit
Table 6	Demographics by Awareness Closure	Before /During	All
Table 7	Sources of Information on Closure	Before /During	All
Table 8	Demographics of Those with Flexible Hours	During	All with flexible hours

Table B.3 Tabulations in IRG Report

Title	Description	Before /During Closure	Respondents
Table 1	Travel Route Before by Travel Route During	Before /During	All
Table 2	Travel Mode Before by Travel Mode During	Before /During	All
Table 2A	Change in Travel Mode by Gender	During	All
Table 2B	Change in Travel Mode by Age	During	All
Table 2C	Change in Travel Mode by Employment Status	During	All
Table 3	Trip Purpose First / Final Stop	Before	All
Table 4	Trip Made During by Purpose Before	Before /During	All who continued to travel
Table 5	Travel Time Before	Before	All
Table 6	Travel Time During	During	All who continued to travel
Table 7	Change in Travel Time	Before /During	All who continued to travel
Table 8	Travel Time Before, by Route	Before	All
Table 9	Travel Time During, by Route	During	All who continued to travel
Table 10	Change in Departure Time	During	All who continued to travel

Table B.3 (cont'd) Tabulations in IRG Report

Title	Description	Before /During Closure	Respondents
Table 11	Change in Arrival Time – First Stop	During	All who continued to travel
Table 12	Change in Final Arrival Time	Before /During	All who continued to travel
Table 13	Return Trip Travel Time	Before	All
Table 14	Difference in Trip / Return Trip Travel Time	Before	All
Table 15	Return Trip Travel Time	During	All who made return trip
Table 16	Change in Return Trip Travel Time	Before /During	All who made return trips before/during
Table 17	Change in Parking Location	Before /During	All who continued to travel by car
Table 17A	Change in Parking Cost	Before /During	all who continued to travel by car
Table 18	Gender of Transit Users	During	All who switched to transit
Table 19	Age of transit Users	During	All who switched to Transit
Table 20	Employment Status of Transit Users	During	All who switched to Transit
Table 21	Consideration for Using Transit by Change in Mode	Before /During	All who continued to travel not by transit
Table 22	Awareness of Closure by Gender	Before /During	All
Table 23	Awareness of Closure by Age	Before /During	All
Table 24	Awareness of Closure by Employment Status	Before /During	All
Table 25	Sources of Information re Closure	Before /During	All
Table 26	Opportunity for Flexible Working Hours	During	All workers
Table 27	Change in Working Hours	During	All with flexible hours